# CRITICAL TECHNOLOGY: OSTP REPORT

## HEARING

BEFORE THE

SUBCOMMITTEE ON
TECHNOLOGY AND COMPETITIVENESS

OF THE

## COMMITTEE ON
## SCIENCE, SPACE, AND TECHNOLOGY
## U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED SECOND CONGRESS

FIRST SESSION

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APRIL 25, 1991

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[No. 20]

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Printed for the use of the
Committee on Science, Space, and Technology

U.S. GOVERNMENT PRINTING OFFICE

44-691 ≈≈ WASHINGTON : 1991

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# CRITICAL TECHNOLOGY: OSTP REPORT

THURSDAY, APRIL 25, 1991

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS,
*Washington, D.C.*

The subcommittee met, pursuant to notice, at 2:00 p.m. in room 2325, Rayburn House Office Building, Hon. Tim Valentine [chairman of the subcommittee] presiding.

Mr. VALENTINE. We'll go ahead and get started. We have a good turnout, I might say, for these circumstances and this time of the week. We'll attempt to proceed with this.

At the outset, I have an opening statement, but I will defer to the distinguished Chairman of the full committee who is here with us today and who would like to introduce one or more of the witnesses and make an opening statement.

Mr. Brown?

The CHAIRMAN. Thank you very much, Mr. Chairman. I appreciate your indulgence. I have been looking forward to this hearing. I commend you for the work that you have put into it, and the ones that you plan as a follow-on. I do want to stay for as long as I can. Let me make a brief opening statement and then, as a part of my responsibilities as a Californian, say a few good words about Dr. Shank, who is here this afternoon.

Let me say that the publication of OSTP's Report of the National Critical Technologies panel may some day be seen as a landmark in American science and technology policy. The release of this document is a clear demonstration of the growing consensus in this Administration that the Federal Government must play a vital role in increasing the strength and robustness of high technology industry in the United States.

This report, coming on the heels of a summary document published by the Independent Council on Competitiveness makes a clear and unassailable case for the need to abandon old models of technology policy and create a new strategy for National economic development in a global marketplace.

As the OSTP Report states, discovery, development, and deployment must be integrated and viewed as concurrent, rather than sequential activity. This statement, coupled with the release of OSTP's U.S. Technology Report last September reflects a substantial turn around in thinking on the part of the Administration. I congratulate the President and my good friend, Dr. Bromley, for their open mindedness.

May I interject that I do not want to make it seem that this is too much of a revolutionary change. I think it is more of a evolutionary development. Probably the overall impact of that change will not be appreciated until we have more opportunity to observe the consequences.

It has been just over a year since the Director, Craig Fields, was removed from his job in what seemed to many of us to be an overly ideological response to his resumed support for what some members of the White House Staff then deemed industrial policy. I don't want to rejudge whether or not that actually was the case. But, if that act represented a low water mark in the Administration's attempt in come to terms with high technology competitiveness, then the publication of the Report on National Critical Technologies is a clear signal that the tide has changed.

With the growing recognition that critical technologies are a crucial element of our national well being, it is my firm hope that Congress and the Administration will be able to work together in a bipartisan way to forge and implement a new science and technology policy for the 21st century.

Now, Mr. Chairman, if I may be further indulged to say a word about Dr. Shank—I think the committee knows that he currently has taken over the role as Director of the Lawrence Berkeley Laboratory, a noted institution, supported by the Department of Energy. He came to that position after 20 years of distinguished research at the AT&T Bell Laboratories, which many members of this committee have visited over the years. I won't outline the scope of his research activities, but they are extremely important in the development of many of the critical technology areas that this report focuses on.

He returned to California to become Director of the Laboratory, and at the same time, he became a faculty member at the university where he is the Professor in the Departments of Physics, Chemistry, Electrical Engineering, and Computer Sciences, which boggles my mind. I guess he is able to handle all that. In addition, he is member of both the National Academy of Engineering and the National Academy of Sciences. He is a member of numerous scientific societies, and has received a large number of medals, prizes and awards, for which he is to be congratulated. He was also a Regents' lecturer at the University of California in 1984.

I think California is fortunate to have an outstanding scientist of this sort. The Federal Government and the Department of Energy area extremely fortunate to have him in the position which he now holds. I won't ask you how we were able to compete with the Bell Labs in terms of salary, but maybe there were some other inducements that brought him back to California. I'm happy to see him here with this distinguished panel this afternoon.

Mr. VALENTINE. Thank you, Mr. Chairman.

We hope that today is going to be remembered as a pivotal event in our attempts—and I think that Chairman Brown alluded to this—to begin preparing the United States as a major force in the technology driven industries of the 21st century.

Today we will hear from the White House and from other agencies on a very important document: the Office of Science and Technology Policy's Report from the National Critical Technologies

Panel. This report is being released today and lists this panel's conclusions as has been stated on which technologies must move into development and commercialization if the United States is to remain the economic force, or indeed, is to regain a position as the economic force, as some would say, which is the basis of our standard of living, and if we are to continue to be a dominant force in the world militarily.

The hearing is being held jointly with the Subcommittee on Research and Development of the House Committee on Armed Forces, although we are advised that the Chairman of that subcommittee, Mr. Dellums, had an emergency situation arise in his State of California and will not be able to participate with us.

We welcome here today, the members of the Subcommittee who are present and, as I stated, our distinguished, not now, but until a short while ago, new Chairman of the Science, Space and Technology Committee, Mr. George Brown, of California, who made the opening remarks to you.

The Committee on Science, Space, and Technology was coauthor of the legislation, Section 841 of Public Law 101- 189, requiring the OSTP to get into the critical technologies business and the document we are discussing today is the first critical technologies report prepared under that section.

The report identifies 22 key critical technologies which have been separated into six categories and, in my opinion, has done a good job of laying out the technological implications of the competitive challenge we face in keeping America both strong and prosperous. Organizations such as the Council of Competitiveness, the Aerospace Industries Association, and the American Society of Mechanical Engineers have drawn up their own lists as have other countries. These reports continue to identify many of the same technologies. There is a growing consensus on what technologies are important today, so we hope to move beyond lists to begin to consider what steps America must take to reach the finish line with commercial products based on these technologies, and to begin to better understand what government resources rightfully should be applied in meeting these goals. We must, therefore, identify an industry-led strategy for achieving these objectives.

As we must focus today on moving these technologies forward, there are some questions that we want to pursue with our agency witnesses: Is there a national strategy to focus the Nation on our technology vision for the future and how we, as a Nation, plan to get there? What is the role of your agency in these critical technology developments? Are there critical technologies that do not have an advocate in the government?

This Subcommittee has more than a one day commitment to the problem. In the weeks to come, this Subcommittee will be continuing to focus on these critical technologies with additional hearings and a great deal of thought, I hope, and effort. We will do our part, I believe, to bring the most important technologies into the commercial marketplace labelled, "Made in America," as often as possible.

I would recognize, at this time, the distinguished member of our Subcommittee from the State of California, Mr. Dana Rohrabacher.

[The prepared statements of Mr. Valentine and Mr. Dellums follow:]

# OPENING STATEMENT

## CHAIRMAN TIM VALENTINE

Subcommittee on Technology & Competitiveness

Critical Technology - OSTP Report

April 25, 1991

We hope today is going to be remembered as a pivotal event in our attempts to begin preparing the U.S. to be a major force in the technology driven industries of the 21st century. Today we will hear from the White House and from other agencies on a very important document: the Office of Science and Technology Policy's Report from the National Critical Technologies Panel. This report is being released today and lists this panel's conclusions on which technologies must move into development and commercialization if the United States is to remain the economic force which is the basis of our standard of living and if the U.S. is to continue to be a dominant military force. The hearing is being held jointly with the Subcommittee on Research and Development of the

House Committee on Armed Services. We welcome the members to this hearing.

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additional hearings and with a great deal of thought and effort. We will do our part to bring the most important technologies to into the commercial marketplace labelled made in America as often as possible.

I look forward to hearing testimony from members of the Critical Technologies Panel and agency representatives on this first report.

**OPENING STATEMENT**
**RESEARCH AND DEVELOPMENT SUBCOMMITTEE**
**25 APRIL 1991**

THANK YOU, MR. CHAIRMAN. I ALSO WELCOME THE DISTINGUISHED PANEL HERE THIS AFTERNOON TO DISCUSS THE SUBJECT OF "CRITICAL TECHNOLOGY." THE SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT OF THE ARMED SERVICES COMMITTEE IS CONCERNED ABOUT OUR STATURE AND POSITION IN THE GLOBAL TECHNOLOGY RACE AND OF OUR ABILITY TO COMPETE IN THAT RACE IN THE DECADES TO COME. THE AUTHORIZATION COMMITTEES OF THE HOUSE AND SENATE AGREED ON THE CONCEPT OF "CRITICAL TECHNOLOGIES" A FEW YEARS AGO -- BOTH TO EMPHASIZE CERTAIN IMPORTANT AREAS OF TECHNOLOGYBY AND TO NARROW THE VIEW OF THE VERY COMPLEX WORLD OF TECHNOLOGY IN WHICH WE MAKE DECISIONS FOR SCIENTIFIC ADVANCEMENT.

DR. HERZFELD, WHO APPEARED BEFORE OUR SUBCOMMITTEE JUST TWO DAYS AGO ON THE DEFENSE TECHNOLOGY BASE, INDICATED THAT THE PACING AND MANAGEMENT OF THE VARIOUS POCKETS OF SCIENCE AND TECHNOLOGY ACTIVITY HAS GROWN SIGNIFICANTLY AND INITIATIVES THAT WE MAY BEGIN HERE IN THE CONGRESS ARE NOT AS EASILY INTERWOVEN INTO THE CURRENT COMPLEX SCIENTIFIC FABRIC AS THEY USE TO BE. THEREFORE, WE NEED TO GAIN A BETTER PERSPECTIVE OF HOW ALL OF OUR CURRENT NATIONAL SCIENTIFIC AGENCIES AND ACTIVITIES CAN SYNERGISTICALLY WORK TOGETHER TO HELP THE U.S. KEEP COMPETITIVE, ESPECIALLY IN THE "CRITICAL TECHNOLOGIES" WHICH APPEAR TO BE THE LEADING INDICATOR AS TO HOW WELL WE WILL BE ABLE TO COMPETE IN THE WORLD MARKET PLACE AND IN DEFENSE.

MY FINAL POINT IS THAT THE CONGRESS RECOGNIZES THAT PROBLEMS EXIST IN THE TECHNOLOGY AND PRODUCT DEVELOPMENT CONTINUUM AND WE ARE READY TO HELP, BUT I AM CONCERNED ABOUT WHAT I THINK IS THE CURRENT MISSING ELEMENT. THAT IS A FRAMEWORK THAT BINDS YOU ALL TOGETHER IN A SYNERGETIC MANNER TO MAKE MORE EFFECTIVE OUR SCIENTIFIC INVESTMENT. I SOLICIT YOUR COMMENTS ON THIS ISSUE.

I YIELD BACK MY TIME, MR. CHAIRMAN. THANK YOU.

Mr. ROHRABACHER. Thank you, Mr. Chairman. I guess I should thank both chairmen here with us today, Chairman Brown, as well.

Everybody knows that for America to remain the leader, both economically and militarily of this planet, that we are going to have to rely on our know how and our technology. That was never brought home more clearly to me than when I visited the Soviet Union in 1985.

I remember that with a group of young Russian citizens, at the right moment I pulled out a jar of Skippy peanut butter to show them what America was all about, to get right to it. The fact is that I was told before I left that the Soviet Union doesn't produce peanut butter. It was beyond me that we were afraid of a super power that couldn't produce peanut butter.

So when the young people wanted to know what America was all about, I took this jar of peanut butter out of my suitcase and said, "Would you really like a taste of what America is all about?" As they were tasting the peanut butter, which was just an incredible treat for these young people, one of them pointed to the jar and said, "What are the black marks on the side of that peanut butter jar?" I said, "Well, I'm glad you asked that question. Those are the marks where when we check out at the food store, the computer picks up the price, notifies the inventory, and gives you an itemized bill." They got together and they conferred with one another and then one of them stepped forth and said, "That's what we don't like about you Americans, you're always lying." Computers at a food store—they just couldn't believe it. It was just beyond them that we had computers at work at a food store.

The fact is that during the 1980s, the United States put computer technology to work throughout our economy. We had millions and millions of hours of work being done by these computer chips that are made out of sand. That was not happening in the Soviet Union.

While I left the Soviet Union and saw what an advantage we had over them because of this technology, I really felt that Communism was doomed. In fact, I believe that it was America's technological lead, as well as our courage, as well as our commitment, that have brought about the great potential we have for peace on this planet today, and the demise of this evil force that threatened mankind for 40 years.

I think our commitment to SDI unnerved them during the same visit. SDI was on everyone's lips. I'll never forget sitting across from my Russian counterpart—I worked at the White House at the time—and they said, we could just have peace if you just wouldn't move forward with this SDI nonsense that threatens the stability of the world. My retort always was, "Well, you know, the Strategic Defense Initiative is only one of many new technologies America has ready to bring on- line. Why should we stay behind simply because you can't keep up?" At the end of these meetings, I could see how unnerved they were by that response. This is what I believe brought the leaders of the Soviet Union to their senses.

As we know, in the Gulf War, our technological lead kept our casualties down. I believe it was America's technology, again, as well as the commitment and bravery of our soldiers and our na-

tional leaders that brought victory to that conflict at a very low price.

The same is true with economics. As a matter of fact, the same is more true with economics. There are people who work hard in every part of the world. All of you have probably traveled to other countries, especially to under- developed countries. Why are under-developed countries under- developed? Why do they have so little welfare? Is it because the people don't work hard? People of Mexico and the people of other countries who are struggling to improve their lot work very hard. In fact, they come to the United States in order to work hard.

What separates their amount of wealth in their society from our society is the fact that we have made it economically viable to put technology to work and develop new technology for our work places. If we are to remain the leader, economically, in the world, as well as remain a leading force for peace and stability in the planet, we must remain the technological leader of the planet.

There are just two areas that I am going to be listening to during this hearing that are of concern to me. Number one, what is preventing the United States from utilizing the technology that we seem to be developing? Why is it that our industries, when we have technology available are unable to put that technology to use in order to be more competitive than their international competition. Number two, why is it that American technology seems to find its way into the hands of America's competitors? Is there something we can do about that? I am a free trader, yet I don't believe that we can, at the same time, be—you know, we'd have to be Uncle Sam instead of Uncle Sap.

The fact is that a lot of the technology that we produce through defense contracts seems to be making its way into the hands of America's competitors. I am very concerned about this, because if the American taxpayers are going to be subsidizing the development, especially of Aerospace technology, for us to be selling that technological capability to other countries seems insane. I, personally, am looking at legislation that would prohibit the same to foreign corporations of technology, not of finished products, but of technology to foreign-owned corporations, that would then permit them to use these technologies that have been developed by defense contract and use them in competition with the United States.

So, Mr. Chairman, I applaud you, and applaud Chairman Brown for being here today with us to show his support for this vital concept. I am looking forward to this hearing.

Thank you.

Mr. VALENTINE. Thank you, sir.

The Chair recognizes the gentleman from Florida, Mr. Jim Bacchus.

Mr. BACCHUS. Thank you, Mr. Chairman. I'll be brief. I'm eagerly awaiting the testimony by each of these gentlemen.

I would like to say a special word of welcome back to Dr. Robert White. Dr. White, I very much appreciated being with you at my District, at the University of Central Florida in the Central Florida Research Department a few weeks ago. I applaud you for taking the time to go out in the country where the people are, and the emerging technologies are, to see all that is being done. I know you

share with me that those kinds of ventures merely reaffirm our faith in the American spirit and American enterprise.

Thank you, Mr. Chairman.

Mr. VALENTINE. Thank you, sir. I'll recognize, at this time, Congressman Don Ritter.

Mr. RITTER. Thank you, Mr. Chairman. I want to commend you for your leadership in holding this important hearing on this most important report.

As anyone who saw last week's segment on critical technologies on "60 Minutes" knows, we may lead the world in basic research in science and Nobel Prizes, but the sorry fact is, that in far too many cases, our competitors are commercializing new American technologies faster than we are.

The report is a blueprint of identification of critical features of America's technological landscape. It identifies 22 technologies critical to America's future. But, it also says that making a list is not sufficient. Technology development must be followed by technology deployment, the development of products, and processes based on the technologies.

This conclusion is refreshing. Our success in the 21st century will depend on our ability to take the science and technology that we develop in the laboratory and create products and processes to enhance our standard of living and provide jobs for American workers and wealth to American communities. I really believe that we are on the threshold of a new era where America, as a Nation, reconsiders its priorities and makes manufacturing—yes, making things, creating things, for both the domestic and international markets—makes manufacturing the crown jewels to be nurtured, polished, burnished, and set on a pedestal, for all the world to see.

As a Nation, we are lagging behind our competitors in the processing and manufacturing technologies which are essential to rapid deployment of critical technologies. We have ignored, in America, manufacturing and processing for 30, 40 years. Frankly, the Federal Government, in its focus on the Federal R&D economy, divorced to some large extent from the private sector economy, bears some responsibility. So it's good to see that Federal Government is in here seeking to recoup.

The report is right on target, Mr. Chairman, with its emphasis on focusing on manufacturing throughout the development cycle, integrating product and process design more effectively, and targeting those processes which show the greatest promise for commercial viability. The economic miracle of Japan is based directly on production, on manufacturing of the quality imperative that defines a relentless pursuit of perfection, while we here, to some extent, ignored manufacturing and were driven by the philosophy, "if it ain't broke, don't fix it."

We are changing, and this report will help us to change faster. I commend Dr. Bromley and the National Critical Technologies Panel for developing this fine report, and I hope that the report will serve as a catalyst for more activity.

Mr. Chairman, I look forward to working with you as this subcommittee takes a closer look at individual critical technologies. I welcome our distinguished witnesses, and look forward to their input.

Mr. VALENTINE. Thank you, sir.

The first of two panels consists of Dr. William Phillips, Associate Director, Office of Science and Technology Policy in The White House; and, has been previously introduced, Dr. Charles V. Shank, Director, Lawrence Berkeley Laboratory.

The Chair has taken the liberty of asking Dr. Robert White, the Under Secretary of Commerce, Technology Administration, to sit at the table with this panel. I understand that Dr. White has to leave here by 4:00. We'll get to you by then. I think, to preserve as much of the orderly process as we can, we'll proceed with Dr. Phillips and Dr. Shank.

So I recognize Dr. Phillips at this time, followed by Dr. Shank, and then Dr. White. I would say to all of you that as you've heard many times as you visited with us, your prepared statements will appear in the record in toto. We ask you to summarize if you can.

Dr. Phillips?

## STATEMENT OF DR. WILLIAM PHILLIPS, ASSOCIATE DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, THE WHITE HOUSE

Dr. PHILLIPS. Chairman Valentine, Chairman Brown, and members of the committee, thank you for giving me the opportunity to present the report of the National Critical Technologies Panel.

I am here today in my capacity as Chairman of the panel, and the views I express represent those of the panel. Fortunately, however, we have a number of panel members here who will also be testifying.

You have a copy of the report, so I will not repeat much of it in detail. However, I would like to touch on the background, methodology, and philosophy that underlie the final list of critical technologies set forth by the panel. I will also briefly compare the list with those issued by the Department of Defense, Department of Commerce, and private sector Council on Competitiveness.

The National Critical Technologies Panel was appointed in 1990 in accordance with the Defense Authorization Act for Fiscal Year 1990. Seven of the thirteen panel members were from the Federal Government; the Department of Defense, Department of Energy, Department of Commerce, and National Aeronautics and Space Administration that were specified by the Act to have representation. The remaining nine members, three from government and six from the private sector, were appointed by the Director, Office of Science and Technology Policy (OSTP).

Mr. VALENTINE. Let me ask the appropriate staff person if you can do something about the lights, we want to accommodate the people who want to preserve our images for posterity, but we also would like to be able to see.

[Laughter.]

Dr. PHILLIPS. Let me just point out what I consider to be an important feature of the panel that is mandated by the law. It truly consisted of both private sector and government people. We have three of our panel members here today: Dr. Shank from Lawrence Berkeley Laboratory, Dr. White from the Department of Commerce, and Dr. Charles Herzfeld from the Department of Defense.

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We also have John White from NSF who was a very important contributor to this.

So it was truly a catholic parameter panel that cut across national security lines, competitive lines. We had ample university representation at the same time on the panel.

We made, also, in this particular study a special effort to receive briefings from a number of other groups, both in government and in the private sector, who were looking at related issues. I would particularly like to mention the private sector Aerospace Industries Association, the Computer Systems Policy Project, and the private sector Council on Competitiveness, with which we have had fruitful interactions. They were very generous in sharing their knowledge and insight with us.

The Council on Competitiveness, as you well know, has just recently issued its latest report, Gaining New Ground in Technology Priorities for America's Future, last month. This report contains much in the way of thoughtful analysis, and I commend it to you as a document well worth reading.

What I would like to show you at this time is—again, I know that you have the report; however, I would like to show you the 22 critical technologies at this particular point. Because, the point I want to make, and this is one that you've also made—both Chairman Valentine and Chairman Brown—is that there is a consensus that has developed, which I think is very important.

I think, among other things, it permits us to say that we do know what the critical technologies are, whether or not they are being pulled from the Defense Secretary or whether or not they are being pulled from the economic sector, or for other national needs, such as energy security, and so on. We know what they are. Okay, let's get on with the problem, at this point. Let's get on with doing something about it.

The basic, the main divisions, as you will see up there, are in the materials section and the manufacturing section, information and communications, biotechnology and life sciences, aeronautics and surface transportation, energy and the environment. We have selected—you'll see several things about this, first off. That is, the materials area, the manufacturing area, information and communications area, are very basic areas to all of our needs.

They are things, unless we have very prominent positions, in all of the sub-technologies under these main ones—one can say that not only does our economy have problems, but, quite frankly, our Defense Secretary has problems, as well. These are the important, major areas that we must retain a prominent position in.

Now, one of these I'd like to speak to, just for a couple of moments here, which is illustrative of what we have here. That is, for example, in the materials area. We have selected five major categories of technologies in the materials area. Now, the interesting thing is that very many of the other technologies in, say, the manufacturing, information, biotechnology, aeronautics, energy and environment, depend on the materials area.

What I'm trying to say is that these technologies are not to be considered in isolation. They are terribly interrelated with each other. Unless you are strong in the materials area, you have real problems in the manufacturing, information, biotechnology, and so

forth. The same is true, as has been pointed out, in the manufacturing area. It's the area where we have done the least well over the past—particularly the past 20 years, vis-a-vis, the competition overseas. It's the area that needs a great deal of attention. It needs a great deal of attention from our industry. Certainly the Federal Government must do everything that it can to promote this area as well. But, it is an area of very great concern to us. So these are very interrelated types of activities that we have here.

I would like to show now just a little comparison. I think it's already to evident to most people, but there is a consensus now on these critical technologies. For example, what one is looking at here are the comparisons between the critical technologies that were identified in this latest National Critical Technology Study; those that were carried out by the Department of Commerce, the Emerging Technologies which appeared last May. This particular next one is the Defense Critical Technologies, which appeared last March, and there will, shortly, be another one coming out.

The point that I want to make, and it has already been made here before, is that there is really a remarkable correspondence between the technologies, even though quite different criteria were employed in the selection. For example, in the selection of the National Critical Technologies, we used joint criteria; that is, defense pull, manufacturing pull, competitiveness pull. I want to emphasize that point. The criteria here was not pure science or even pure technologies. These were pulled from the national needs side, defense needs, competitiveness needs, energy security needs, environmental needs, and so forth.

The Commerce Emerging Technologies were an identification of critical technologies, based on the criteria of very major markets by the year 2000. The Defense Critical Technologies, of course, were predicated on the need for the Department of Defense to maintain the military strength of the United States.

Now, the next overhead will show the comparison of the National Critical Technologies with the recently published Council on Competitiveness Critical Technologies. Here, the Council on Competitiveness criteria were based on the needs of the economy. Nine industrial sectors were identified by the private sector Council on Competitiveness. They then identified the critical technology needs in these. Again, you will see a remarkable correspondence between the National Critical Technologies and the Council on Competitiveness.

All one is saying at this point is there is a concurrence that the critical technologies are identified. I would say also, that there is a great deal of overlap with critical technology identifications that have been carried out by the Japanese and the European Economic Community. That is, one can take these areas given at this point, and one needs to get on to what can be done about it.

Okay, I'll finish up here in just a minute, but I would like to say that in the environment of intensifying global competition that we find ourselves in, it is not enough to come up with new ideas or even to develop these ideas into new technologies. The ultimate pay-off comes when technologies are deployed, whether for military or commercial purposes. In the commercial world, successful firms are not necessarily the discoverers and the developers of the latest

innovation, but those that are able to bring swiftly the associated products to market.

Those firms must also maximize profits in order to sustain through reinvestment a continuing flow of both new and improved products derived from research and development. Therefore, it is not identification of critical technologies, nor even the development of those technologies that is important. It is what we do with them that is important.

You can cut that off, Tom.

Where do we go from here? As I've emphasized, our focus should not be on continuing to generate new lists, which all say about the same thing, but on doing something to improve the U.S. position. The panel did not address implementation, but the Critical Technology Institute, which is in the process of being established, under the fiscal year 1991 Defense Authorization Act, will be concerned primarily with follow-up to the panel's report.

We need to have a better understanding of overseas models in order to assess the nature of the competition. The value of research and development consortia need to be addressed. The role of the Federal laboratories needs re-examination. We also need to examine regulatory barriers, the limited available pool of capital, and other inhibiting factors that may be affecting our ability to compete internationally.

One of the things that you will hear in the subsequent discussions is, are there initiatives that are being taken? The Federal Government has very serious responsibilities, but so does the private sector, so does the Congress, so does the Administration. The thing that we have got to learn to do— and I think I really quite agree with comments that have already been made—but I think we are nearing a consensus. I am hoping that we have reached our low point and are beginning to come up.

I think there is a great deal of hope, not the least of which are the very serious, non-parochial, non-self-serving discussions that you frankly hear in private sector groups, like the Council on Competitiveness. They are coming forward now, simply not asking for more here and more there for parochial reasons. They are looking at the problems from a broad perspective. I think it's important that we do exactly the same thing in the Administration.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Phillips follows:]

**STATEMENT BY WILLIAM D. PHILLIPS**

**Chairman, National Critical Technologies Panel**

**Before the Subcommittee on Technology and Competitiveness**
**Committee on Science, Space, and Technology**
**and**
**Subcommittee on Research and Development**
**Committee on Armed Services**
**United States House of Representatives**

**April 25, 1991**

**STATEMENT**
**by**
**William D. Phillips**
**Chairman, National Critical Technologies Panel**
**Before the Subcommittee on Technology and Competitiveness**
**Committee on Science, Space, and Technology**
**and**
**Subcommittee on Research and Development**
**Committee on Armed Services**
**United States House of Representatives**

Mr. Chairman:

Thank you for giving me the opportunity to present the report of the National Critical Technologies Panel. I am here today in my capacity as Chairman of the Panel, and the views I will express represent those of the Panel. You have a copy of the report, so I will not repeat much of the detail in it. However, I would like to expand a little on the background, methodology, and philosophy that underlie the final list of critical technologies set forth by the Panel. I will also briefly compare the list with those issued by the Department of Defense, Department of Commerce, and private sector Council on Competitiveness.

## National Critical Technologies Panel

The National Critical Technologies Panel was appointed in 1990 in accordance with the Defense Authorization Act for Fiscal Year 1990. Seven of the 13 Panel members were from the Federal government, and the Department of Defense, Department of Energy, Department of Commerce, and National Aeronautics and Space Administration were specified by the Act to have representation. The remaining nine members, three from government and six from the private sector, were appointed by the Director, Office of Science and Technology Policy (OSTP).

In appointing these nine members, OSTP tried to achieve a wide representation of expertise and experience, bearing in mind that the study was focused on technologies "essential for the long-term national security and economic prosperity of the United States." We were fortunate to have the private sector represented by Dr. Robert W. Lucky, an expert in electronics, information, and communications from AT&T Bell Laboratories; Dr. Richard C. Messinger from Cincinnati Milacron, an expert in manufacturing and machine tools; Dr. Alexander Rich, renowned researcher in molecular biology and professor of biophysics at M.I.T.; Dr. Charles V. Shank, Director of the Department of Energy's Lawrence Berkeley Laboratory and an expert in optics and electronics; Dr. Albert R.C. Westwood, Vice President for Research and Technology at Martin Marietta Company, one of the major U.S. aerospace corporations; and Mr. James Worsham, former President of Douglas Aircraft with wide experience in aviation and aircraft manufacturing. These Panel members brought with them invaluable knowledge, not just about technologies but also about broader issues of commercialization and competition in the international marketplace.

In addition, we were ably assisted by Panel members representing the National Science Foundation and National Institutes of Health. Although the specified size of the Panel precluded appointing experts in other fields of technology, we worked very closely with the Department of Agriculture, Department of Transportation and the National Institute of Standards and Technology to ensure that we had a wide perspective. This diverse representation, along with the charge from Congress, accounts for the broader range of the Panel's list of critical technologies than is seen

in the Department of Commerce's list of emerging technologies or the Defense critical technologies.

We also made a point during the course of the study to talk to and receive briefings from a number of other groups, both in government and the private sector, who were looking at related issues. I would particularly like to mention the private sector Aerospace Industries Association, the Computer Systems Policy Project, and the Council on Competitiveness with which we had fruitful interactions. They were very generous in sharing their knowledge and insight with us. The Council on Competitiveness issued its latest report "Gaining New Ground: Technology Priorities for America's Future" last month. The report contains much in the way of thoughtful analysis, and I commend it to you as a document well worth reading.

## Methodology

The National Critical Technologies Panel approached its task with the benefit of prior government studies that I have already mentioned: The Defense Critical Technologies Plan (issued annually beginning in 1989), and the Commerce Emerging Technologies report issued in 1990. We quickly realized that determining the level of aggregation at which the critical technologies should be presented was an important consideration. We could all agree on the general categories such as materials, manufacturing, biotechnology, and so forth. However, these categories were too broad to be useful. On the other hand, focusing on very specific technologies such as zone refining of silicon or magnetic bearing applications in high-speed machining would have resulted in a list that was much too long and not likely to be comprehensive.

Our choice, then, was to select categories that were more detailed than the major technology areas but which were groupings of related but more narrowly focused technologies. Thus, for example, Micro- and Nanofabrication represents a family of technologies which include lithography techniques, thin films, surface treatments, and microdevices. In a few cases, as in High-Performance Metals and Alloys, the Panel added subtitles (shown in parentheses) to delineate the technologies of interest within a very broad category.

I mention all this because the Panel found no perfect way to deal with the problem of aggregation. In the end it is a matter of judgment, choice, and consensus; and every expert group faced with the same issue will deal with it somewhat differently. You will see this when you look at the tables in our report that compare the Panel's critical technologies with those nominated by other groups. There is general agreement among all of them, taking into account the slightly different objectives and boundary conditions that each group operated with. Therefore, as a practical matter it is best to concentrate on the overall message of these reports rather than get bogged down in the minutiae of methodology and taxonomies.

We were guided in our final selection by the following considerations:

- National needs
  - -- Does it contribute to U.S. competitiveness in world markets?
  - -- Does it enhance national defense?
  - -- Does it help our energy security?
  - -- Does it improve our quality of life?

- Importance/Criticality
  - -- Does it give us an opportunity to lead the market?
  - -- Will it lead to improvements in performance, quality, or productivity?
  - -- Does it provide leverage to stimulate success in other technologies?
  - -- Will the U.S. be vulnerable to damage if the technology is held exclusively by another country?

- Market Size/Diversity
  - -- Does it form the foundation for many other technologies?
  - -- Will it exert a major economic impact?

I realize that there are varying degrees of overlap among these criteria, but they were employed as guides, not as absolute figures of merit. As has been the case in related studies, the Panel was able to agree on a final compilation of technologies without necessarily agreeing completely on definitions or on the relative importance of various criteria.

## Critical Technologies

The final list of 22 critical technologies selected by the National Critical Technologies Panel is:

### MATERIALS

- Materials synthesis and processing
- Electronic and photonic materials
- Ceramics
- Composites
- High-performance metals and alloys

### MANUFACTURING

- Flexible computer integrated manufacturing
- Intelligent processing equipment
- Micro- and nanofabrication
- Systems management technologies

### INFORMATION AND COMMUNICATIONS

- Software
- Microelectronics and optoelectronics
- High-performance computing and networking
- High-definition imaging and displays
- Sensors and signal processing
- Data storage and peripherals
- Computer simulation and modeling

BIOTECHNOLOGY AND LIFE SCIENCES

- Applied molecular biology
- Medical technology

AERONAUTICS AND SURFACE TRANSPORTATION

- Aeronautics
- Surface transportation technologies

ENERGY AND ENVIRONMENT

- Energy technologies
- Pollution minimization, remediation, and waste management

The order in which the technologies are listed does not reflect a prioritization. In fact, the interesting feature of technologies today is that they are all interrelated. For example, continuing advances in computer software are necessary to support development of advanced capabilities in simulation and modeling, high-performance computing, and intelligent processing equipment. The only distinction on the list is between the first three general categories, Materials, Manufacturing, and Information and Communications, and the last three. The first three can be considered as "building blocks" for virtually all sectors of the economy. The other three categories are more akin to major areas of applications. However, all 22 technologies are critical to future U.S. national security and/or economic well-being.

You will note that the Panel did not include technologies that will only be realized in the longer term, such as nuclear fusion. We also excluded technologies associated specifically with space exploration because they had insufficient direct

impact on national security and economic prosperity. The Panel did recognize, however, that space exploration will continue to stimulate advances in many of the critical technologies.

We included in our Panel's report a comparison between our critical technologies and those selected by Commerce, Defense, and the Council on Competitiveness. As I mentioned earlier, there is general agreement among them, allowing for slight differences in criteria, levels of aggregation, and definitions. I think the point to be made here is that knowledgeable people confronted with this task can generally agree on which technologies are critical. The real challenge we face is not generating a list but doing something about it. Also, the considerable overlap between technologies that are critical to both national security and economic prosperity attest to the importance and pervasiveness of these technologies in our lives today.

## Implications

The key point that the Panel wants to emphasize is that technology alone cannot ensure national security and economic prosperity. Technology can make an important contribution to the future of U.S. national interests, but only if we learn to utilize it more effectively.

The Panel believes that the U.S. science base is unmatched in the world today. Science is the wellspring from which all technology is derived, and our broad scientific base allows us to generate technology in abundance. Support for the basic

sciences needs to be broadly based in order to maximize the yield of useful advances. In contrast, technology development and deployment, because of the time and resource commitments involved, require greater selectivity and concentration of resources than is appropriate for the basic sciences.

However, in an environment of intensifying global competition, it is not enough to come up with new ideas, or even to develop those ideas into new technologies. The ultimate payoff comes when technologies are deployed, whether for military or commercial purposes. In the commercial world, successful firms are not necessarily the discoverers and developers of the latest innovation, but those that are able to swiftly bring the associated products to market. Those firms must also maximize profits in order to sustain through reinvestment a continuing flow of both new and improved products derived from research and development. Therefore, it is not the identification of critical technologies nor even the development of those technologies that is important; it is what we do with them that matters.

Future U.S. competitive success requires a fundamental change in the way U.S. industry competes in the marketplace. Our research institutions and businesses must place greater emphasis on deployment of new technologies. Furthermore, discovery, development, and deployment must be integrated and viewed as concurrent rather than sequential activities. As one of our Panel members expressed it: " U.S. industry must be infused, from the boardroom to the factory floor, with a relentless desire to constantly improve both product and production methods."

Mr. VALENTINE. Thank you, sir.
Dr. Shank.

## STATEMENT OF DR. CHARLES V. SHANK, DIRECTOR, LAWRENCE BERKELEY LABORATORY

Dr. SHANK. Mr. Chairman and members of the subcommittees, it is a pleasure to be here today.

There is perhaps no area more important to the future of this Nation's economy than the subject of this report. The ability of American industry to compete in the global marketplace and to provide high value added, high technology American jobs is linked to our ability to provide leadership in these critical technology areas.

As a scientist with both industrial and national laboratory experience, I believe that only the Federal Government can take the long term perspective essential to assessing the Nation's technological needs. My own view of what a critical technology places the emphasis on those research areas where investment of Federal funds could leverage these technologies and have a potentially pervasive role in the American economy over the next 10 to 15 years.

In writing this report, the panel members were mindful of the question posed to us by Senator Bingaman, author of the amendment establishing the panel. In meeting with Senator Bingaman, he asked, "How can Congress decide which technical areas are most important to our Nation?" Our report describes 22 technological areas that we hope will begin to answer Senator Bingaman's question.

With that background, I want to focus my discussion on just two of the critical technologies identified in the panel's report, to illustrate how the report might be used. I want to discuss some specifics of these technologies, why the panel included them, and my perspective on the proper Federal role in accelerating American research and development in these areas.

The first area is materials synthesis and processing. The excitement of this field lies in the future opportunity to literally build new materials, in some cases, atom by atom. We envision engineering new materials with currently unattainable and unique properties.

The excitement of this field is rapidly spreading. A major initiative in materials synthesis and processing is under consideration for inclusion in the fiscal year 1993 budget. Success in this area will require tools and the approach of fundamental science in a long term commitment. For this reason, there will be a special role for national laboratories which have the unique experience in long-range materials and facilities available to the scientific community.

The second technology I want to address is micro- and nano-fabrication. The most widely recognized need for this technology is the manufacture of semiconductor chips. One promising area is the use of very short wave lengths for fabricating even more dense integrated circuits and, therefore, more functions in a single chip.

A new source of x-rays will be coming on line in 1993 at the Lawrence Berkeley Laboratory. The Advanced Light Source will be the world's brightest source of so-called "soft" x- rays in the spectrum

ideal for x-ray photo lithography. We are currently working with industrial and academic scientists to design a program that will rapidly advance this field.

This initiative would develop an integrated system for research into the industrial use of projection x-ray photo lithography.

The Federal Government has an important role in supporting research. Since World War II, the Federal Government has assumed the responsibility for funding basic scientific research. It's time to expand the Federal mission to include fundamental technological research.

Many people use DARPA as an example of directed technological research for our national defense, and believe that a civilian DARPA be created. While DARPA has done a great job for the defense sector, I believe that the Federal Government would be more successful in supporting civilian technology research expertise wherever it exists in its civilian agencies.

In the Department of Energy, what I believe is needed, is support for fundamental civilian technology research. What I propose for D.O.E.'s Office of Energy Research is a technology research program having two parts, with broad benefits for our economic competitiveness.

The first program would support generic pre-competitive technology research on critical technologies where D.O.E. facilities have a particular expertise.

The second would fund projects to move technological innovations into the private sector. This program would jointly fund cooperative research and development agreements and national laboratory projects where initial technology has been developed and a clear market opportunity exists, but additional work is required before commercial applications are identified. I believe the Department of Energy and the Nation would greatly profit from a $50 million technology research program.

In closing, Mr. Chairman, it has been a pleasure to serve on the National Critical Technologies Panel. I hope that we have provided your Subcommittee Members with a road map of where we should go and what my testimony gives is some helpful advice on how we might get there.

Thank you.

[The prepared statement of Dr. Shank follows:]

**Testimony of Charles V. Shank**
**Director, Lawrence Berkeley Laboratory**
**before the**
**House Science, Space and Technology Subcommittee on**
**Technology and Competitiveness**
**and the**
**House Armed Services Subcommittee on**
**Research and Development**

**Thursday, April 25, 1991**

Mr. Chairmen and members of the Subcommittees, it is a pleasure to be here today to discuss the National Critical Technologies Panel report. Since this is the first time I have appeared before your Subcommittees, let me begin with a brief introduction. I became the director of Lawrence Berkeley Laboratory in September, 1989, after having spent the previous twenty years at the AT&T Bell Laboratories, culminating as the director of its Electronics Research Laboratory. My own research field is the study of ultrafast processes with short pulse lasers, work that has resulted in specific new technologies and a number of patents. The views that I express today will have the perspective of an industrial researcher tempered with my more recent experience as a Department of Energy national laboratory director.

I was honored to be chosen by the President's science advisor, Dr. Bromley, to serve on the National Critical Technologies Panel. There is perhaps no area more important to the future of our nation's economy than the subject of this report. Our world is becoming more competitive, and more dependent upon advanced technology, every day. The ability of American industry to compete in the global marketplace, and to provide high-value added, high technology American jobs, is inexorably linked to our expertise and ability to provide leadership in these critical technological areas.

As in any policy debate, there are those who argue that these concerns and decisions should remain in the private sector, and that the Federal Government should remain on the sidelines during this battle. As a scientist whose instincts are still in industry while adjusting to the environment of a national laboratory, I believe that only the Federal Government has the long-term perspective essential to assessing the nation's technological needs for the future. What I hope we have produced in this report is an initial guidebook for those industrial and Federal policymakers who need to consider the next steps in determining the appropriate responses in each of the identified technological areas.

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We began our deliberations, of course, by defining what a "critical technology" is. The Panel's definition is those "areas of technological development which are essential for the long-term national security and economic prosperity of the United States." I agree with this definition, but my own preference would be to place primary emphasis on those research areas where an investment of Federal funds could have major leverage on those technologies that will have a potentially pervasive role in the American economy and where the payoff will be long-term (10-15 years).

In writing this report, the Panel members were mindful of a question posed to us by Senator Bingaman, author of the amendment establishing the Panel. In meeting with the Panel members, Senator Bingaman asked "how can Congress decide" which technological areas are most important to our nation. Our report describes 22 technological areas that we hope will begin to answer Senator Bingaman's question.

As I mentioned before, I came to the Panel in a rather unique role—no longer an industrial researcher, and just beginning my tenure as director of a national laboratory. This provided me with an in-depth understanding of the needs and opportunities in the industrial research sector, combined with an emerging view of how the Federal Government can most effectively enhance the country's technological strength.

With that background, I want to focus my discussion on just three of the critical technologies identified in the Panel's report, to illustrate how the report might be used. I want to discuss some specifics of these technologies, why the Panel included them, and my perspective in the proper Federal role in accelerating American research and development in these areas.

The first technological area is **materials synthesis and processing**. The report defines synthesis as the development of new materials or new techniques to produce existing materials, and processing as the preparation of these materials into finished products. Synthesis and processing of materials can be viewed as a continuum of research rather than as two separate and distinct activities, for it is often the structure of the materials that ultimately determines how they will be processed and formed into a product.

In examining this field, perhaps the most exciting course for the future will be the opportunity to create new materials at the atomic level—literally to build atom by atom. Rather than tailoring existing materials for a particular use, we envision engineering new materials with unique properties. By modifying material structure we can tailor the electronic, structural, optical, magnetic, thermal or almost any property we desire. The applications of these materials will be as wide-ranging as the imagination. From lighter, stronger construction materials to new medical technologies, and new electronic devices—there will be no limit to the possibilities of these artificially engineered materials.

The excitement in this field is rapidly spreading. A major initiative in materials synthesis and processing is under consideration for inclusion in the FY 1993 budget. An increase in Federal support for this fundamental area of research could have major impacts on American materials competitiveness. To quote the Panel's report, "U.S. scientists traditionally have concentrated their studies on the properties of novel materials rather than on their synthesis, which has often been left to foreign laboratories", Materials synthesis and processing has had a hard time finding an intellectual and academic home in American research universities. Yet it requires the tools and approach of fundamental science and a long-term commitment. For this reason, there will be a special role in this initiative for the national laboratories, which have considerable experience in long-range materials research and unique facilities that are already available to the broader scientific community.

At the Lawrence Berkeley Laboratory, we have been working at the forefront of new materials research for many years. At the Center for Advanced Materials, scientists work on materials ranging from high temperature superconductors to ceramics and semiconductors, with ongoing guidance from industrial advisory boards. They have at their disposal, as does the nation, the National Center for Electron Microscopy. This Center contains the most powerful electron microscope in the United States, and the highest resolution microscope in the world. The latter microscope, the Atomic Resolution Microscope, can actually image individual columns of atoms and allow differentiation between types of atoms. This kind of imaging is essential to future advances in both materials processing and synthesis. The Department of Energy national laboratories have a long-range research perspective in this area and a wealth of basic expertise which can be used to accelerate this initiative.

The second, and closely related, critical technology I want to address is the field of **micro- and nanofabrication**. The Panel's report describes this field as fabricating and manipulating materials at the microscopic and atomic level. Perhaps the most widely recognized need in this area is fabrication of the next generation of semiconductor chips, where the goal is increasing the density of components and thus a number of functions on the chip. Beyond the integrated circuit, there is a world of potential uses for nanofabrication, including biotechnology and optical electronics.

This is a field in its infancy, with much yet to be learned about constructing devices which have a size of a few hundred atoms. One promising area of research is the use of x-rays with very short wavelengths for fabricating denser integrated circuits. Research into x-ray lithography is proceeding at a rather measured pace in this country, considering its importance to our nation's investment in the semiconductor industry and the competition from overseas. A promising new source of x-rays will be coming on-line in 1993 at the Lawrence Berkeley Laboratory. The Advanced Light Source will be the world's brightest source of so-called "soft" x-

rays in the spectrum ideal for x-ray lithography research. We are currently working with industrial and academic scientists to design a program that will rapidly advance this field and retain our nation's leading role in the world semiconductor industry.

This initiative, in collaboration with industry, universities, and other national laboratories, would develop an integrated system for research into the industrial use of projection x-ray lithography for integrated circuit production. It would provide specific x-ray beamlines for assessing optical component performance and evaluating advanced lithographic techniques. The initiative would also establish an in-house capability for nanostructure patterning, synthesis, and processing. These capabilities, and the resulting technologies, will have both defense and civilian applications.

Micro- and nanofabrication, however, is more than the next generation of semiconductor chips. Expertise in physics, chemistry, materials science, and electrical engineering needs to be strengthened and encouraged to explore the world of reduced dimensionality for all types of devices and processes. This is where this research field coincides with the critical technological area of materials synthesis and processing. Our national research agenda must cover the spectrum from a fundamental understanding of new materials and devices at the atomic level, to their eventual fabrication and mass production.

The third critical technology I wish to address is **energy storage**, and particularly batteries. Future advances in battery technology are essential for a successful electric vehicle industry as well as for smoothing peak electric power generation requirements. Although overall U.S. energy use is rising slowly, demand for electricity as a percentage of that use is growing more rapidly. This trend will be compounded by the future demands of electric vehicles, more office automation equipment and a general trend towards electrification of our society. Advanced batteries will provide the ability to make the most efficient use of centrally generated power, as well as contributing to cleaner air in urban environments.

The Department of Energy has sponsored a fundamental research program on advanced batteries for many years. The program has recently developed some promising new ideas for advanced batteries. One particularly exciting concept, now patented and licensed to a small California start-up company, is a solid-state lithium battery that is environmentally benign and may deliver the same amount of power as a lead-acid battery with half the weight. This could have a major impact in many sectors of the economy, including consumer electronics such as portable computers. This and other exciting new concepts are being explored.

In my opening remarks, I mentioned that I wanted to address what our nation could do to advance research on, and eventual application of, these critical technologies. For most, if not all, of these areas, the Federal Government has an important role to play in supporting this research. Despite the eventual industrial applications, the short-term view of industrial investment combined with the declining state of our economy precludes industrial financial involvement in the early stages of this fundamental research. Since World War II, the Federal Government has assumed the responsibility for supporting basic scientific research in our nation. The world is changing, and support for basic technological research will be as important to our economic and national security future as basic scientific research. It is time to expand the Federal mission to include basic technological research.

When this subject arises, many people use DARPA as an outstanding example of directed technological research for our national defense, and urge that a civilian DARPA be created. While DARPA has done a great job for the defense sector, and has resulted in many civilian applications, I believe that the Federal Government would be more successful in supporting civilian technology research expertise wherever it exists in its agencies. The Department of Commerce has the Advanced Technology Program, the National Science Foundation its Science and Technology Centers, and the Department of Agriculture its Agriculture Extension Services.

What is missing is support for fundamental civilian technology research within the Department of Energy. The Defense Programs portion of DOE has a program on Technology Commercialization whose FY 1992 budget proposal is $32.4 million. From my understanding of the program, however, it is designed to facilitate commercialization of technologies already developed through the weapons research laboratories. It is time for the nation to obtain value from the Department of Energy's massive investment in fundamental research. What I am proposing for the Office of Energy Research in DOE and its laboratories is a Technology Research program that would support two complementary research programs with broad benefit to our national economic competitiveness.

The first program would support generic, pre-competitive technology research of long-term interest to American industry. This program would support those critical technology research areas where DOE facilities had a particular expertise. These multi-year projects would be expected to have some level of industrial participation, such as advisory committees and boards, exchanges of scientists or contributions of funding, equipment or materials.

The second program would fund projects with the specific goal of moving technological innovations into the private sector. This program would jointly fund Cooperative Research and Development Agreements (CRADAs), as well as support national laboratory projects where an initial technology has been developed, a clear market opportunity exists, but additional work is required before a specific industrial investor is identified. There is a small program within DOE's Office of Energy Research that supports this work, the R&D Laboratory Technology Transfer program, but its proposed FY 1992 budget is only $4.9 million. I believe that the Department of Energy, and the nation, would greatly profit from a Technology Research program funded at a level of $50 million.

In closing, Mr. Chairmen, it has been a pleasure to serve on the National Critical Technologies Panel. It is truly a critical time, both for these technological areas and for our nation. There are difficult decisions to be made about our future economic course. I hope that our panel has provided your Subcommittee members with a roadmap of where we should go, and that my testimony gives some helpful advice on how we should get there.

Thank you.

Mr. VALENTINE. Thank you, sir.
Dr. White.

**STATEMENT OF HON. ROBERT WHITE, UNDER SECRETARY OF COMMERCE, TECHNOLOGY ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE**

Dr. ROBERT WHITE. Thank you, Mr. Chairman.

I'm delighted to be able to participate in this important hearing, both as a member of the panel and as a customer for this report.

Your letter of invitation raised four very important questions about the concept of critical technology, each of which has special importance to the Department of Commerce. Without further ado, let me discuss each of those in turn.

First, you asked what we mean by "critical". You asked whether today's technology challenge is a normal state of affairs or whether international competition is more serious than usual. When Commerce uses the term "critical", we use it to refer to technologies that either lead to new products in industries of substantial size or provide large advances in productivity or quality. They are also important because they will drive the next generation of technological development.

The panel's report puts it in similar terms. They have to form the foundation for many other technologies or exhibit strong linkages to many segments of the economy. In short, we can't look at technologies in a vacuum, but must understand their inter-connection with products, markets, industries, and other technologies. Otherwise, we can't possibly appreciate their importance.

Now, when we think of technologies as critical, we are thinking of technologies that cut across major portions of the industrial landscape. Is technology development normal? Is international competition more serious? There are, in fact, big differences today. One, the process of converting technology into commercially viable products and processes appears to be different than we have traditionally understood. We tended to think of technology as the physical embodiment of a scientific idea, and technology development as a conveyor belt process that proceeds from breakthrough to lab prototype to development and on to a product—as sort of a relay race.

We really need to think of it as a concurrent, integrated process involving design, manufacture, and marketing—more like a basketball game in which the entire team moves forward by passing the ball back and forth.

A second feature that changes the game, as we know it, is that the key to turning out better and better products is not just the mass production systems, as we have always understood it—what I call traditional manufacturing. Now, today, it's a digitally based system, predicated on world class quality, the ability to control inventories and costs, the ability to respond quickly to changing markets and technologies and the ability to satisfy the needs of individual customers. In short, it's a process we now call "lean production."

A third factor of particular importance today is that the development costs involved are enormous. In many cases, they are too

large for individual corporations, and often they are too large for any one investor to ever recover his benefits.

Technology development has become so complex that it is no longer a scalable process; that is, there is often a critical level below which you can not receive any benefit. This may be less of a problem for some of our competitors, who are organized industrially; that is, they are vertically integrated so that technological development can be efficiently exploited by many different end users, minimizing the risks to any one of them.

Such organization, when coupled with the adoption of advanced manufacturing technologies, gives our competitors the ability to find more applications for technologies and to constantly turn out new generations of product, denser chips, more efficient engines, small electronic gadgets, and get them to the market quickly.

If the situation has changed so dramatically, then it's only fair that we move on to your second question. How come the report states "no course of action?" Don't we need a national strategy? I don't think it is very helpful to try to chart a course until we have general agreement on where we are and where we want to be. In my view, there is far too little understanding and agreement of the factors that I have just described. There is far too little understanding and agreement of the challenges that U.S. firms face.

Where I think the report makes its major contribution to public policymaking in that it gives a candid assessment of where we stand and that all the factors that I have described above are reflected in its analysis. It forthrightly acknowledges that both the public and the private sector have to do some serious rethinking about their relative responsibility.

For far too long, we have taken comfort in the relatively simple notion that Government was fulfilling its essential obligation by creating a strong science base, and industry would be fully able to use that base to create innovative, high quality cost competitive products and processes. But, not all Federal research has been successfully utilized by industry. Indeed the report forces us to ask some hard questions about the continuing usefulness of this model.

Perhaps more importantly, it recognizes that government has to be concerned about industry's ability to translate the breakthroughs in the lab into new and better products and processes.

So I think it is fair to say that once we have agreement that the game has changed dramatically, and that each player has to reassess some long cherished notions, then we have a basis for intelligent discussion of where we go from here.

That brings me to your third question. What are the implications for Commerce? Well, there are several. First of all, it provides me with a personal challenge. I chair the FCCSET Committee on Industry and Technology. That committee has undertaken as its mission improving the effectiveness of the Federal R&D investment. Our approach to this enormous challenge is to use the critical technologies list as a basis for surveying what actually exists in our Federal R&D portfolio. That is something that has never been done. Our plan is to get U.S. industry involved in critiquing this investment and identifying areas where we can work together for our mutual benefit.

Just last week the full FCCSET Committee approved our plans for carrying out the cross cut for materials, and putting together a coherent government-wide plan for the 1993 budget cycle. We have already inventoried $1.2 billion that we've spent on developing manufacturing technologies, one of the critical technologies. This will be the basis for another thrust of this FCCSET Committee.

Within the Technology Administration in Commerce itself, we have put together a team to assess where we stand in these technologies, relative to the rest of the world—where industry expects to be in the next five to ten years, and how it expects to get there. It's composed of experts from the private sector and Federal agencies, and will draw upon expertise in particularly the data basis in other parts of D.O.C., such as EXA and ITA.

The report also helps us as program managers in bringing focus to our generic pre-competitive research efforts. Where appropriate, it can help us make choices on which generic technologies may be the most logical to fund in such activities as our Advanced Technology Program, with the actual award decision, of course, based on merit selection criteria. In fact, the first 11 awards involved a number of critical technologies, including electronics and information systems, manufacturing systems and superconductors.

The report reinforces our efforts to encourage the adoption of advanced manufacturing techniques, especially by small and medium sized businesses. This means encouraging the formation of more and more flexible computer-integrated manufacturing facilities, making maximum effective use of our own Automated Manufacturing Research Facility and ensuring that our manufacturing Technology Centers are effectively transferring valuable technology firms within their regions.

From a broader perspective, the report challenges Commerce to work closely with industry to develop strategic partnerships. This will help business explore the possible benefits arising from efficient pre-competitive forms of collaboration, not just between horizontal competitors, at early pre-competitive stages, but involving teams made up of non-competing companies throughout the whole process of innovation, manufacturing, and marketing. I expect that other agencies, such as Defense, will find it similarly useful.

That brings me to your last question. To what extent can we expect D.O.D. to assume significant responsibility for the Nation's overall technology base?

D.O.D., as a practical matter, has concentrated more and more on defense-specific needs, especially in the era of a decreasing budget. It will have an enormous stake in the outcome of our efforts to encourage a manufacturing renaissance in the United States, not only as a means of keeping manufacturing costs under control, but to balance its dependence on foreign-based suppliers of machinery and components, and to make it possible to upgrade existing systems.

However, when we look at the big picture, we note that defense is only a small part of the overall manufacturing sector of the economy. D.O.D. informs me that its investment programs currently amount to less than 5 percent of the non- service sector of the economy. I, therefore, expect D.O.D. to take increasing advantage

of technology developments that first emerge in the civilian sector, as it uses its far limited resources for more military-specific goals.

Accordingly, we cannot rely on military programs to bootstrap our industrial technology goals, however much we may agree that the military has a general interest in a healthy industrial base. That is a problem that has to be solved by industry itself, and any solution must be industry led.

So the report that we are talking about today is a stake in the ground. No doubt there will be differences of opinion, and this will promote healthy dialogue. Researchers will go to their managers with renewed convictions that their technology is on the list. Government funding agencies will see increased numbers of proposals in these areas. Basically, we now have a basis on which to make a variety of analyses.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Robert White follows:]

STATEMENT OF

DR. ROBERT M. WHITE

UNDER SECRETARY OF COMMERCE FOR TECHNOLOGY

ON

THE REPORT OF THE NATIONAL CRITICAL TECHNOLOGIES PANEL

BEFORE THE

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS

(HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY)

AND THE

SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT

(HOUSE COMMITTEE ON ARMED SERVICES)

APRIL 25, 1991

Thank you. I am delighted to participate in this important hearing on the National Critical Technologies Report, both as a member of the Panel that produced it as well as a "customer."

Your letter of invitation raised four very important questions about the concept of critical technologies, each of which has special importance to the Department of Commerce. So without further ado, I'll plunge right in and discuss each in turn.

First, you asked what we mean by "critical," whether today's technology challenge is a normal state of affairs, or whether international competition is more serious than usual.

When Commerce uses the term "critical" we use it to mean technologies that either lead to new products and industries of substantial size or provide large advances in productivity or quality. They are also important because they will drive the next generation of technological development.

The Panel's Report puts it in similar terms: They have to form the foundation for many other technologies or exhibit strong linkages to many segments of the economy.

In short, we can't look at technologies in a vacuum but must understand their interconnection with products, markets, industries and other technologies. Otherwise, we can't possibly appreciate

their importance.

For example, the abandonment of the VCR market was not just a failure to recognize the potential profitability of the videocassette recorder but a failure to think strategically and appreciate interrelationships. The technology embodied in the VCR led to new products, such as portable CD players and camcorders. The VCR created new markets, such as pre-recorded tape. It created a source of demand for key technologies, such as semiconductors.

So when we think of technologies as critical, we are thinking of technologies that cut across the entire industrial landscape.

Is technology development today "normal?" Is international competition more serious? In a nutshell, what's different today is:

One, the process of converting technology into commercially viable products and processes appears to be different than we have traditionally understood it.

We have tended to think of technology as the physical embodiment of a scientific idea and technology development as a neat, conveyor belt process that proceeds from breakthrough to lab prototype to development of a commercial prototype, and so on - sort of a relay race.

We really need to think of it as a concurrent, integrated process involving design, manufacture and marketing, more like a basketball game in which the entire team moves forward, constantly handing off to each other.

A second feature that changes the game as we know it is that the key to turning out better and better products is not just the mass production system as we have always understood it, but a digital based system predicated on world class quality, the ability to control inventory and related costs, the ability to respond quickly to changing markets and technologies, and the ability to satisfy the needs of individual customers.

A third factor of particular importance today is that the costs involved are enormous today. The costs of developing a single technology, such as a 64 megabyte DRAM or building a single semiconductor plant, are huge.

When you consider further that technologies and industries are interrelated, as I noted, it becomes easier to understand why firms often find it so hard to justify making the necessary investments, especially when accounting concepts do not fully measure the value of such key determinants of competitiveness as software development, just-in-time delivery, and the ability to change product rapidly or meet surge demand.

Collectively, this means that technology development is not always scalable. That is, there is often a critical level of investment below which you don't receive a benefit. This may be less of a problem for some of our competitors who are organized industrially - that is, they are vertically integrated - so that technological developments can be efficiently exploited by many different end users and risk to any one is minimized.

Such organization, when coupled with the adoption of advanced manufacturing technologies, gives our competitors the ability to find more applications for technologies and to constantly turn out new generations of products - denser chips, more efficient engines, smaller electronic gadgets with a bewildering array of features - and get them to the market easily.

If the situation has changed so dramatically, then it's only fair that we move on to your second question: How come the Report states no "course of action?" Don't we need a national strategy?

I don't think it is very helpful to try to chart a course until we have general agreement on where we are and where we want to be. In my view, there is far too little understanding and agreement of the factors I described above and far too little understanding and agreement of the challenges that U.S. firms have to contend with.

Where I think the Report makes its major contribution to public

policymaking is that it gives a candid assessment of where we stand, that all of the factors I described above are reflected in its analysis, and it forthrightly acknowledges that both the public and private sector have to do some serious re-thinking about their relative responsibilities.

For far too long, we have taken comfort in the relatively simple notion that government was fulfilling its essential obligation by creating a strong science base and industry was fully able to use that base to create innovative, high quality cost competitive products and processes. But not all federal research has been successfully utilized by industry.

The Report forces us to ask some hard questions about the continuing usefulness of that model. Perhaps most importantly, it recognizes that Government has to be concerned about industry's ability to translate breakthroughs in the lab into new and better products and processes.

This Administration has begun to address that concern by proposing the creation of government-industry consortia in areas ranging from energy to high performance computing. In addition, the Administration has proposed, in its FY 92 budget, substantial increases in an array of applied R&D areas, including a 30% increase in high performance computing, a 34% in energy R&D, a 23% increase in aeronautics R&D, a 13% increase in fusion research with emphasis on

engineering design, and of particular personal concern, a 15% increase in NIST's intramural programs.

So I think it is fair to say that once we have agreement that the game has changed dramatically and that each player has to reassess some long-cherished notions, then we have the basis for intelligent discussion of where we go from here. And that brings me to your third question: What are the implications for Commerce? There are several:

First, it gives me a personal challenge. I chair the FCCSET Committee on Industry and Technology which has undertaken as its mission improving the effectiveness of the Federal R&D investment. Our approach to this enormous challenge is to use the critical technologies identified in this Report as the basis for surveying what actually exists in our Federal R&D portfolio.

Our plan is to get U.S. industry involved in critiquing this investment and identifying areas where we can work together for our mutual benefit. Just last week the full FCCSET Committee approved our plans for carrying out a crosscut for materials and putting together a coherent, government-wide plan for the FY 1993 budget cycle.

OMB has already inventoried the $1.2 billion we spend on developing manufacturing technologies. This will be the basis for another

thrust within our Committee.

Within the Technology Administration, we have put a team together to assess where we stand in these technologies relative to the rest of the world, where industry expects to be in the next 5-10 years, and how it expects to get there. It is composed of experts from the private sector and federal agencies and will draw upon the expertise and data bases of other parts of DOC, such as BXA and ITA. I look forward to reviewing these studies with representatives from U.S. industry, possibly through workshops organized by professional and trade associations.

The Report also helps us as program managers in bringing focus to our generic precompetitive research efforts. Where appropriate, it can help us make choices on which generic technologies may be most logical to fund in such activities as the Advanced Technology Program, with the actual award decision based on merit-based selection criteria. In fact, the first eleven awards involved a number of identified technologies, including electronics and information systems, manufacturing systems, and superconductors. NIST's intramural program initiatives also support industry in some of these critical technologies.

Other parts of TA will also benefit. For example, it tells our experts at NTIS what kind of information is most likely to be in demand and helps them plan accordingly.

The Report reinforces our efforts to encourage the adoption of advanced manufacturing techniques, especially by small and medium sized businesses. This means encouraging the formation of more and more flexible, computer integrated manufacturing facilities, making maximum effective use of our Automated Manufacturing Research Facility, and ensuring that our Manufacturing Technology Centers are effectively transferring valuable technologies to firms within their regions.

From a broader perspective, the Report challenges Commerce to work closely with industry to develop a Strategic Partnership Program. This Program will help business explore the possible benefits arising from efficient pro-competitive forms of collaboration -- not just between horizontal competitors at early pre-competitive stages, but involving teams made up of noncompeting companies throughout the process of innovation, manufacturing, and marketing.

The Report challenges us to explore various forms of industry arrangements. GE has achieved notable success by keeping its R&D under one roof and deploying new technology to its various manufacturing divisions. Many large companies in the U.S., on the other hand, develop industry-specific R&D goals and pool resources for generic R&D. We need to understand these models better.

And I expect that other agencies, such as Defense, will find it similarly useful. And that brings me to your last question: To what

extent can we expect DOD to assume significant responsibility for the Nation's overall technology base?

DOD, as a practical matter, has concentrated more and more on defense-specific needs, especially in an era of decreasing budgets. It will have an enormous stake in the outcome of our efforts to encourage a manufacturing renaissance in the United States, not only as a means of keeping manufacturing costs under control, but to balance its dependence on foreign-based suppliers of machinery and components, and to make it possible to upgrade existing systems.

However, when we look at the big picture we note that Defense is only a small part of the overall manufacturing sector of the economy. DOD informs me that its investment programs currently amount to less than 5% of the nonservice sector of the economy and it is slated for significant budget reductions in the 1990's.

I expect DOD to take increasing advantage of technology developments that first emerge in the civilian sector as it uses its more limited resources for military-specific goals.

Accordingly, we cannot rely on military programs to bootstrap our industrial and technology goals, however much we may agree that the military has a general interest in a healthy industrial base. That is a problem that has to be solved by industry itself and any solution must be industry-led.

In conclusion, the Panel has performed a valuable public service in identifying these technologies. They have affirmed the basic premise that a nation with a rich scientific base such as ours should not attempt to identify a limited number of technologies for intense government support. Rather, it reflects that a substantial number of emerging technologies should be under simultaneous development in order to diversify risk and broaden the future industrial base.

The private sector, of course, must also play a substantial role in developing these technologies. The Administration has proposed to provide for this base through the broad program of government R&D I noted earlier as well as its initiatives to make the R&E tax credit permanent and to extend the National Cooperative Research Act to joint production ventures.

We look forward to working with industry to identify the next steps. Thank you.

Mr. VALENTINE. Thank you, Dr. White. Thank all of you.

I want to provide ample time for not only members of the Subcommittee on Technology and Competitiveness to be able to question the members of the panel, but also the members of the Armed Services Subcommittee on Research and Development. So I will make my questions brief and then try to kind of clean up if there is anything left at the end. After I have asked a few questions, I will yield again to the distinguished Chairman of the full committee.

Let me kind of begin our discussion here, from our vantage point, by asking a general question about a show business topic. A person in whom I have confidence contacted me yesterday, I believe, and asked me if I would look at a tape, which I did last evening, and again today, of a program known—and I hate to mention it—as "60 Minutes." I could probably get in trouble, but that's not likely, but I never thought much of that program. I thought of it as mostly show business. With the things that I have seen in my limited dealings with it, I had what I thought was a good working personal knowledge for myself, but they messed it up.

I'll tell you what I saw on the tape that my friend brought to me was quite scary. This person, who is a scientist, said that there was a lot of truth in it. It said, in effect, that all of the great outflowing of national pride that we have demonstrated with our yellow ribbons and our salute to the troops when we have displayed to the world American technology in preserving the peace in the Persian Gulf War, that so much, if not the major part of that, would not have been possible without Japanese technology, the optics, and the chips, and so on that we use.

At the end of that scary tale, they ended up by saying, "Write your Congressman," and that the country is on a slide down to who knows where. They didn't say to contact your favorite Chief Executive Officer of any corporation. It said to contact your Congressman.

We sit here and talk about and appropriate money for research and development, and, I think, some of the witnesses have talked about that we need additional support for research, if we are to continue to be as involved as we have in the past —that is, the Federal Government—that it is time for the Federal Government to begin to get involved in research that affects production and salesmanship.

I'll try to turn that into a question, but—

[Laughter.]

Mr. VALENTINE. What do you all have to say about that?

Dr. Shank.

Dr. SHANK. Well, I think that the point is one of great concern to me. The United States has made an enormous investment in fundamental science with the hope that that science would ultimately find its way into a technology and into an industry in the U.S. I believe that we have to take not only responsibility for investing in fundamental science, but another very hard look at how we get the maximum output from the investment that we have made in fundamental research by beginning to fund and to do work in research on the technologies themselves to provide an opportunity to both train our people and to make the fruits of that research move quickly into the private sector.

Mr. VALENTINE. Is there something fundamentally and basically wrong with the system in this country that makes it a real institutional problem in our translating American inventiveness into salesmanship? Is it the cost of the money? How is it that we can invent and develop all these things—the transistor—and we can't sell them?

Dr. SHANK. Well, let me answer part of that question. Yes, I do think there is something fundamental. I think that the United States industry and government have an adversarial process. I believe in Japan and where we have competitors, people work together in parallel in obtaining research that will ultimately lead to new technologies.

In my own experience in industry, I saw inventions of my own that were developed by one company. Ultimately, we ran against competitors that had six and seven Japanese companies working together. They ultimately brought that invention to market.

I think that we need to learn to work together and to focus our resources in a positive way before these products get to the point where they are manufactured and where success depends on manufacturing and marketing. I don't think any one company can own a technology from beginning to end. I think we need to figure out how to make American industry and the government work in a positive, reinforcing process.

Mr. VALENTINE. The perception is—at least I have the perception that American business has been treated very well by government over the past decades, as far as the tax burden is concerned. It certainly would appear that the amount of money that the taxpayers put in research and development goes up, up, up.

Dr. SHANK. I think I'm talking about something different. I'm really talking about a mind-set, whether you are going to completely own a technology, or whether you are going to distinguish yourself on the basis of being able to manufacture and market that technology. I think too much of our attitude is from an industrial perspective to try to own that entire technology. I think that the government has a tendency to worry about how close we get to supporting a technology and how we go from basic science through technology through something that can actually support industry.

Mr. VALENTINE. Dr. Phillips, are the Japanese not impeded by anti-trust laws?

Dr. PHILLIPS. Sir, could I return to your previous question?

Mr. VALENTINE. Yes, sir.

Dr. PHILLIPS. Briefly, though, if I might, I'd like to put what I think it is in context. I mean, we're not in massive retreat across all of our industrial sectors. For example, our chemical and our pharmaceutical industries are still the dominant industries in the world. Our aircraft industry is doing quite well.

I'm not here to say that the electronics industry—in consumer electronics, we're doing poorly. We're being threatened in other areas, to be sure. But we have to be careful. All I'm saying, sir, is that we have be careful. One has to look at this sector by sector. When one looks at it sector by sector, you are also looking at, in a sense, how directly do you translate science and technology into product. In the chemical industry, the translation is fairly direct from the development of a new molecule, say, to then your chemi-

cal engineers work on processes, then you come up with manufactured products. We do extremely well over there. The pharmaceutical industry also depends on molecules.

So the point that I'm trying to make is that I think we have to be careful that we just don't say that we are in gross retreat across all areas. Now, it's in areas where the distance between the innovation, or what's done in the universities and in our industrial laboratories, in coming up with prototype products, then, where there are great difficulties in translating this into finished product. This is where we have a lot of our problems.

So all I'm saying, sir, is that we need to be careful about, let's say, a general indictment of our industrial system or manufacturing system, and even our governmental system as it's applied to certain to certain of the industries.

Now, to return to your second question, do the Japanese operate differently? Yes, sir, they do operate in ways with respect to interfacing between their government and their private sector. I mean, we all are well aware of really the fairly direct way in which their manufacturing sector, private sector interact. It's a much more indirect thing than we have built in this country, for good reasons, I think.

But, nonetheless, it makes this adversarial relationship that was mentioned by Dr. Shank a real thing. One of the things that we've got to do is to find ways where we get better input from the private sector into what we are doing, both in Congress and the Administration. This is one of our problems. Yes, we do operate differently. But it's not entirely bad, either. There are strengths to our system at the same time.

Dr. ROBERT WHITE. I might add that another factor in this is that we do have an economic environment here which I think is not conducive to long-term investment. I think that technology is very particular in the fact that it does take a long time to bring things to fruition. We tend to think that we are being bombarded every day by new technology. But, if you take any one development and trace it back, you'll find that it may have taken 10 years to bring it to market. Somebody had to have the wherewithal and the patience to do that.

Today our system is structured as such that this is not encouraged. It's too easy to move large amounts of money in and out. It's almost a roulette kind of game that some of these investments are playing. So I think that we must find a way to stabilize the investment environment.

Mr. VALENTINE. Well, I have one final question and then I will yield to Mr. Brown.

Are there areas in industrial achievement in the United States where we still have a significant lead and are not losing ground? If there are, please tell us where they are.

Dr. PHILLIPS. Sir, I mentioned the chemical industry and the pharmaceutical industry. Our aircraft—

Mr. VALENTINE.—aircraft—but, we're losing there. I mean, we're still ahead, but we're—

Dr. PHILLIPS. There is tough competition, and a lot of this is because of some direct subsidies into that system. That's where we

don't do that. I mean, this has permitted the inroads by Airbus into the U.S. aircraft industry. There is no question about it.

Dr. ROBERT WHITE. I think most software-related industries, particularly as surprising as it may sound, are in the manufacturing area. Those advanced manufacturing systems that are based on very elaborate software programs have put us in a leadership position.

Mr. VALENTINE. Mr. Brown.

Mr. BROWN. Dr. Phillips, let me just lead you a little bit into the future here. You have made the point— and I think it's a valid point—that in these six technology areas, there are considerable differences in the situation that exist there.

In some of them, the research and the development and manufacturing are closer together. There are different concentrations of where the research is done in some areas, with energy and the environment, for example. It may be that the Federal Government has a predominant role in the research and possibly in aeronautics, as another example. Whereas, in the pharmaceutical and biotechnology, it's likely to be more supported by the private sector. So each of these sectors represents a different factorial situation.

May I inquire as to whether, as you iterate this process, and move into additional critical technology studies that you may want to focus on these differences and to at least identify the possible different strategies that might be effective for the Federal Government? As an example, the Administration has released a long-term Energy Strategy. Could we look forward to something like this, recognizing the diversity that exists within each of these?

Dr. PHILLIPS. Yes, sir. That's absolutely correct. As a matter of fact, as Dr. White mentioned, he is Chairman of the FCCSET Committee Industry and Technology currently carrying out this initiative on the advanced materials and processing. Certainly the way that individual materials, that is the ceramic—one ceramic in not necessarily applicable to the automobile industry, the aircraft industry, on down the line. In this crosscut, which will lead to Federal initiatives, the points that you are making will be taken into account. That is, this diversity of what is needed in the different kinds of sectors, yes, sir.

Mr. BROWN. Of course, that would require a strong input from the private sector representing each of these sectors in order to achieve that kind of strategy.

Dr. PHILLIPS. In that particular case, if I might interrupt, Mr. Brown, there has been over the past four years, a great deal of input from the private sector into this whole materials area. That is, as I'm sure you are well aware, the Materials Science and Engineering Report that came out from NRC in the Fall of 1989 was very much of a private sector oriented one.

Then, Dr. Bromley has had a series of regional studies going on across the United States to flesh out this report more by private sector, both industry and industry people, and government laboratory people as well, just to do this in the materials area.

Mr. BROWN. Let me phrase one additional question. I don't want to belabor this, but in your list of critical technologies, seven out of the twenty-two are in the information and communications field.

Dr. PHILLIPS. Yes, sir.

Mr. BROWN. I focus your attention on the differences that may exist within this area and the other five. We have a situation in information and communications where the Federal Government determined the goal for the private sector activity. As an example, we set the standards and frequency allocations for the broadcast industry. We determine the intellectual property rights and we changed them, as we did recently in the syndication of certain software program syndication. We determine who will get into what market, as Judge Green did with his modified final judgment.

Have you given special thought to the needs of this complex, inter-related set of technologies and the diverse private sector forces within them as to how that might be done — a strategy could be developed there which is going to have to be more than just, we'll say, supporting additional technology development? The technology development is there. AT&T is doing a lot. There are many other labs. The problem is, uncertainty or lack of an overall policy framework which demands a Federal Government role.

Dr. SHANK. Yes. I couldn't agree with you more, sir. Of course, I think that certain progress was made in this in the studies that led up to the high performance computing and communications initiative. But, it's far from being complete. It is an area—but, I think that Dr. White may want to comment on this—but this is also an area that we plan on spending a great deal of time on in this Critical Technology Institute that we are now in the process of putting together. We can, indeed, get the appropriate private sector input into just the issues that you have been discussing.

Mr. BROWN. There are very powerful conflicting private industry needs here, which is going to complicate the problem. Also, it makes more demanding the need for some Federal leadership, it seems.

Dr. SHANK. I could maybe make a comment on that. I think that there are very clearly cases where government regulation also regulates the pace of technology. Clear cut examples are separate systems for cable t.v. and communications. Other countries are taking different points of view. They are going to push new technologies that we won't push as a result of this kind of technology regulation. I think it's a very complex matter. We have a whole set of reasons why we've done what we've done. But, I think that these things need to be evaluated in the sense that—are we regulating technology, or are we regulating business?

Mr. BROWN. I couldn't agree with you more. The very action of the Federal Government to cut through some of these things is going to unleash tremendous private sector industries, if we can set the grounds rules so that we perceive them as clearly being in the national interest.

Thank you, Mr. Chairman.

Mr. VALENTINE. Thank you, sir.

The gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. I will make my questions brief, Mr. Chairman.

It seems to me that what we are talking about is not necessarily subsidizing and further government research directed, but instead of having the government set some of the ground rules, the private sector resources can more efficiently and effectively be used.

The Chairman mentioned in passing, and I don't remember whether we got back to it or not, whether or not anti-trust laws were getting in the way of our own corporations working together in order to develop new technologies and compete with, for example, the Japanese, who have no trouble in having their corporations work together.

Could I have a short comment from each of you on that.

Dr. SHANK. I certainly wouldn't want to represent myself as a legal scholar in this activity. I do know that the Japanese tend to form groups to work on various targeted technologies. They break apart as these technologies begin to move into a region where they are susceptible to being manufactured. I know that in the United States, we have a tendency to want to develop and own it all within an individual company, and to distinguish ourselves on that basis. I think that is a really tough problem. Part of it is our culture, and part of it is the legal system that we work in.

Mr. ROHRABACHER. Would that same type of structure, in developing the technology—as you say targeted technology— be permitted in the United States under current anti-trust laws?

Dr. SHANK. I don't know the answer to that.

Dr. ROBERT WHITE. I think that there is a Cooperative Research Act that would allow companies to work together, at least in the R&D arena. That is an exercise that is beginning to pick up more and more momentum. The number of consortia registered now is somewhere up over several hundred.

In Commerce, we have put together planned legislation that will allow cooperative production, as well.

Mr. ROHRABACHER. When did that pass—when did that go into effect?

Dr. ROBERT WHITE. The Cooperative Research Act was in 1984.

Mr. ROHRABACHER. So until 1984, it seems that our foreign competitors had a major edge on us by the fact that some of their activities were outlawed in the United States for their American competitors?

Dr. ROBERT WHITE. That's correct.

Mr. ROHRABACHER. Let me just note that in your report, from what I understand—and I will read your report thoroughly, I haven't read it yet, and I'm very grateful to the hard work that has gone into this. What you've said today has really whetted my appetite. I am going to go on an airplane tomorrow to California and I'll read it on the plane.

But, I understand that somewhere in the report, the progress that has been made by the consortia that is producing the National Aerospace Plane is recognized. Just to note, whether it's in, I think, the comparative today, the importance of developing technology is more of a team effort, rather than a team that is handing off the baton as in a race, but more like a basketball team, working together in order to come up with products and put them into the competitive game.

I think the National Aerospace is breaking a lot of new ground. I appreciate the fact that you have recognized this in your report. I would hope that in the future, our aerospace industries, as well as other industries will benefit from this type of approach, as well as the materials and the computers and the different type of technolo-

gy that is coming out of this program. If you have any comment on that, that's fine, but I just wanted to mention that.

Thank you very much, Mr. Chairman.

Mr. VALENTINE. Thank you, sir.

The Chair recognizes the gentleman from Texas, Mr. Edwards, a member of the Research and Development Subcommittee of our companion subcommittee.

Mr. Edwards.

Mr EDWARDS. Thank you, Mr. Chairman.

I have two questions to any of you who might address them. First, is there a long enough track record, yet, at SEMATECH, and Micro-Electronics Computer Consortium to determine fairly whether those types of consortiums will be an effective investment and a model for research and development. Secondly, as long as American managers are reimbursed on an annual and quarterly bonus basis, how do we encourage the private sector to look at long term research, which I think is a real problem for us.

This is for any of you.

Dr. PHILLIPS. Well, Dr. White, of course, has been in involved with the MCC one, but let me just make a couple of comments. First off, I think both the MCC and the SEMATECH Consortium are extremely important—and I don't want to use the word experiment, because sometimes this is taken in the wrong vein—but, I think it is extremely important that this different mode of operation is being attempted, and in both of these cases, be continued. There are evolving. They are trying to find the proper ways to go. At the very minimum, what they have done is to bring together companies that discuss common problems in ways that we simply have not done before.

So in my own view, it is too early to determine what is going to be the impact. In my own view, it is going to be positive. I think it's impossible to know both how positive and what direction it is going to be in. I think it is going to be terribly important, in my view, that we continue both of those.

With respect to this business of—what you are really talking, of course, is the alleged, and I think to a degree of reality, short term, horizon of a good deal of the business management that we have in the United States. A lot of it is due, as you say, to the rewards system that we have set up. A lot of it is due to the different way we have of financing our companies which are not inclined—that is, the type of investments we have now—are not inclined to the long range view, but the short range view.

In my view, this has drastically hurt our companies. That is, we talk about research and development being done in universities, and that sort of thing, but unless industry carries out its own research and development and is able to translate what has been done in universities—and I think it's equally important to generate the R&D needs that they have within—that they are in trouble. One of the first things that gets hit on these short range things are your research and development investments.

So I think this is the sort of thing that one has to look to, in the general way that we regulate, we form taxes, and so forth, but part of it is reflected simply because we don't have the inexpensive, long-term investment capital in the United States.

Mr. EDWARDS. Is there any indication that there are interest rates that have dropped from their high in the double digits down to the prime rate today that the net present value calculations which tend to certainly discourage long term research? I mean, they just don't pay off when you use that type of approach with high interest rates. Is there any indication that lower interest rates for the last decade has increased research at American business at all?

Dr. PHILLIPS. Well, the statistics do not bear it out. It appears that it still is declining.

Mr. EDWARDS. Thank you.

Thank you, Mr. Chairman

Mr. VALENTINE. We recognize, at this time, the distinguished gentleman from Pennsylvania, Mr. Ritter.

Mr. RITTER. Thank you very much, Mr. Chairman.

I want to thank our witnesses for some very excellent testimony, and to commend them on the quality of this report.

First, I would like to just put the discussion in some context. In the "Sunday Times", there was a front page story last week. The headline read, "Manufactured exports provides hope for U.S. economy." So as I think Dr. Phillips said and Dr. White was saying, this is a mixed bag. We're still in this game. The good news of all of this is we're really still in the game, we're still major players. Our exports in manufacturing have jumped, according to this article, by 76 percent since 1986.

It talks about, basically, a two-pronged fork which is done. This one prong is where the dollar has gotten cheaper, and making American products cheaper overseas. The other prong to the fork, which I think is awfully important to serve as context for this discussion—it says here, "More enduring"—more enduring than the dollar being cheaper— "are the sweeping and painful changes undertaken by American managers and workers, which have revived flagging factory productivity." It goes on to talk about the adoption of quality and quality principles and quality processes and the like.

So we have an opportunity here to make some further gains. I guess what I would like to draw out from you is some thoughts about critical technologies and how they get into the system. If America doesn't expand its focus on quality—if we don't develop a quality culture, is our investment in some of these science research development technology—is it going to be lost? Therefore, is it necessary to encompass even within reports such as this, the human dimension to making the overall system work?

This is not a technology—it is not a critical technology the way we refer to it. But, without it, you could have the best technology there, as has been said, but someone else is going to apply it first. Because systemically, they are more engaged in the process of deployment. Are we missing focus as a critical element to these kinds of debates—the focus on the human element—the quality resolution, the absolute essential feature of our deployment landscape?

Dr. ROBERT WHITE. I think you put your finger on it. It's a very important element of this, and that is, the appearance of quality consciousness on a massive scale within American industry. I mean, we have certainly seen that in our administration of the Baldrige Award. I mean, it's just unbelievable. But, I think that we

have to also keep in mind that when we talk about a quality management process, it's not just manufacturing; it's a whole technology innovation process that starts as soon as the light bulb goes off in somebody's head. The quality process nurtures those ideas all the way through staring to think initially about the applications at that early stage. So the whole quality process encourages that. I think that is what we have reason to be optimistic about.

Mr. RITTER. Dr. Phillips.

Dr. PHILLIPS. I couldn't agree more with what you are saying and what Dr. White is saying. We can lose and we have lost a number of our technology advances, simply because of the lack of this quality control, the education of our workers, the way this whole thing is done. There is a culture to doing manufacturing properly. It has not always been the best elements of our culture that have done it.

I think we are learning. Our best companies, first off, are responding to this international competitive threat by pushing very hard on exports. At the same time, when they do that, they usually put plants up in other countries, they learn from other countries, so this is brought back. I think we are seeing that our companies are improving. I mean, there are a number that are improving on this and that are cognizant of what is going on.

Mr. RITTER. Jackson Grayson from the American Productivity Center was in my office earlier today. I said that I had heard the number of 10 percent of American companies are practicing this world class quality. He said he thought it was more like 5 percent. So that is very disturbing. It seems to me that we just can't avoid the focus on this human side of it if we are to succeed.

Again, we could develop the critical technologies here, as we have, to some extent, even in the last decade developed the critical technologies here, but they get deployed elsewhere.

That brings me to the second question - deployment. Deployment is really where it's at. Again, you can have everything vested in the laboratory, and you can win all the Nobel Prizes, and you can even have the best technology out there, but if a small firm in Silicon Valley really takes it to Japan to develop it and deploy it first there because the capability is there, the capital is there, that isn't good for America. We see a lot of that happening.

What I guess my question for you is, it's not just critical technologies that deployment is important for America's success in manufacturing and production and the economy at large. There is so much out there now that is in the catalogs, that's on the shelves that's not being deployed. There is a tremendous gap. Now, you are talking about these top of the line technologies here—the ultimate cutting edge. There seems to be a tremendous backlog, if you will, of technology, that is not quite so critical, but perhaps far more extensive throughout the economy, which is available, but not used.

You find a lot of small companies, medium-sized companies don't have engineering talent, to begin with. They don't know that things are available. They don't have the capital, if they did. To me, that is a critical dimension of technology's ability to impact on the American economy. How do you see that aspect going?

Dr. PHILLIPS. Well, I have a couple of comments, Congressman Ritter. One is that in our critical technologies system, management technologies was one in our manufacturing section. It was explicit-

ly put in to deal with what you are talking about—not necessarily the big break through technologies, but the whole command, control, how do people interact—is implicit in this. We feel very strongly, the same way you do, that this is a critical technology, simply because of its criticality.

But, let me go on to say on your other comments, that we have a lot of technology there. Much of the problem that we've gotten into in the United States is again looking for the big break through in a scientific discovery, and we're going to turn this into a whole new great series of products. One of the ways the Japanese, of course, have done so well, is in this more or less continuous incremental innovation in product improvement. Let's say, this is evolutionary, as opposed to revolutionary, as has been said.

Mr. RITTER. Long term.

Dr. PHILLIPS. Long term, but still looking at these incremental improvements rather than for the discontinuities, more or less. I mean, you have got to be conscious of the discontinuities, but we have tended to look too much for those and not be concerned about the——

Mr. RITTER. Let me ask you this, are we encouraging the discontinuity approach by focusing so sharply on the cutting edge? Again, we can own the cutting edge, but if we don't do what Mr. Edwards talked about and what you responded to—stick with it over the long term—the VCR was 20 years in coming. Until profitability came, it must have been about 20 years—high definition has been about 20 years and there still is no profit to be made. But, you know that the next generation of television is going to bring a heck of a profit to people who make them.

Dr. PHILLIPS. It again has to do with the scope. How far is the investment climate, the vision of the people in industry and, of course, what government needs to do to encourage this kind of thing.

Mr. RITTER. I think unless we focus on that long-term—you see, quality is a long-term deal, because the steps are small and they come over long periods of time. You have to stick with it. It seems to me that unless we deal concurrently with this kind of Federal R&D prioritization—which I think is really good and I've been arguing it for 10 years—unless we have the fundamentals in the economy of investment climate, you know, it's going to be really tough in the next 20 years to be the ones who deploy, as opposed to the ones who innovate and develop.

Dr. PHILLIPS. We spent a good deal of time in the report, I think, making very parallel comments that define and identify technology. But, we basically have to have evolution and almost revolution in the culture with which we approach the manufacturing process in all of those things.

Mr. RITTER. Mr. Chairman, thank you very much for this time. I yield back.

Mr. VALENTINE. Thank you, sir.

The Chair recognizes the gentleman from Arkansas, Mr. Thornton.

Mr. THORNTON. Thank you very much.

I should like to first compliment my colleague from Pennsylvania, Mr. Ritter, for his penetrating questions and the clarity of his

views. I would like to associate myself with the views which have been expressed, that it is important, not only to move at the cutting edge, but to do something about the fundamental qualities that we find in our culture which have put us at some disadvantage in deploying the excellence of our research.

I was recently a participant with a panel with Mr. Dick Elkus, who at one time was head of Ampex. They controlled the patents on the VCR, and were hopeful and prepared to see America move into the production of these home entertainment and useful recording devices. I need not tell anyone here where VCRs are now manufactured.

It seems to me that the issues of anti-trust laws and cultures are also related to a sense to the adversarial relationship that has been referred to by members of the panel; not only, I might say, between government and industry in the regulatory arena, but between one American company and another. You see instance after instance where an American company would never think of walking down the street, even if anti-trust laws would permit it, to negotiate an agreement with a competitor down the street to dominate a marketplace arena, but without hesitation would contact a Japanese or German company in a similar field and negotiate an agreement with that company.

Can we not try to change some of cultural barriers that we have in this country to improve the recognition that we are in competition with a worldwide economy and capability and that the competitor down the street is not necessarily our main adversary.

Dr. Phillips.

Dr. PHILLIPS. Well, I couldn't agree with you more, sir. This really is the inclination, the way we operate. I think, again, part of this is because of the interest of U.S. companies in finding foreign markets and the reciprocity, of course, of Japanese or European countries here. So in a sense, there can be a little bit of a natural alliance. Whereas, the American companies are fighting it out against each other in this market here. There is a little bit of that. But, what you are saying is absolutely true.

Where we generally get U.S. companies working best together is not when they are competitive. I mean, I refer to—there is an arrangement at Sandia or Los Alamos, I've forgotten which, where they are trying to commercialize in the superconductor area, which involves Hewlett Packard and Dupont and Los Alamos. There you can get Hewlett Packard and Dupont working well together because their markets are simply going to be different on what comes out of this thing. We have problems and they do have problems working together.

I think this is one of the virtues of SEMATECH and MCC, that we have gotten companies working together, tentatively perhaps, but to a certain extent. But, I agree with you 100 percent. These are generally not anti-trust problems that we have, either.

Mr. THORNTON. It is not so much the anti-trust legislation as it is the mind-set associated with those regulations, is it not, sir?

Dr. PHILLIPS. This is true, sir. I hate to make this following comment, because I know that there might be at least one and possibly two lawyers here. But, if I was in industry and I would want to, for example, go talk with another company about —this looks interest-

ing, perhaps I should go talk with this individual over there—go talk to my counsel. I'll take along five lawyers and we'll give this a try. Well, you usually just give up in the process.

Mr. THORNTON. I am a lawyer, but had a client who once told me that he was sure that Columbus did not have a lawyer on board his ship, because the lawyer would have convinced him, first of all, that there was nothing to be discovered. Even if it was there, it would be owned by someone else, and he would have convinced him that the problems were too great to make the journey.

Part of the problem is, you express caution. The general mindset, again is what I'm dealing with. Maybe we should have some demonstration projects, like the SEMATECH and others, and high definition television, for example, where we encourage cooperation between different companies and clear a path for American companies and American workmen to enter an area of international competition and to dominate the field. We should say, we're going to clear the path and we're coming through that hole.

Do any of you have any comment about that concept?

Dr. ROBERT WHITE. I think that we speak a little parochially here. One of the areas that we are finding that we can generate many of these cooperative and consortia kind of activities is through the National Institute of Standards and Technologies, NIST. Many of these issues have standards components to them.

Many companies are willing to come together in the neutrality of this, in some sense to work on some of these issues, particularly interface issues. So we are finding that companies are very, very willing to work together. I think that this is an area where they will get the experience and learn that it is not a painful experience, and that it can be beneficial to them.

I might also add, a second thing is that, as you know, one of the requirements of a winner of the Baldrige Quality Award is that that winner share his quality management practices with other companies. We now have nine winners. They are all going throughout the country, working with many other companies, sharing their own quality management practices. That, also, is to bring companies to work together in that case, in terms of their own quality program. So it is happening.

Mr. THORNTON. I think that I should like to also follow along very briefly on a thought alluded to by Chairman Brown when he expressed, I thought, some concern, that so many of the emerging technologies were in communications and service- type areas. I would like to highlight—and I hope that you will join me in thinking it appropriate—to highlight a paragraph from your report on page 37, where you are talking about manufacturing, and you say that "Erosion of the manufacturing base will result in the loss of a significant portion of the services sector employment and trade that depend on it. Failure to maintain world class manufacturing capability would compromise the Nation's ability to compete in domestic and international markets, and would threaten our ability to continued economic growth, and to obtain access to the full range of components and equipment required for a strong national defense."

I would just like to suggest that as we look at emerging technology, that we should be very conscious of the importance of a strong manufacturing base on which to support all of those technologies.

Do you think this emphasis is appropriate, Dr. Phillips?

Dr. PHILLIPS. Absolutely, sir, absolutely.

Mr. THORNTON. Dr. Shank.

Dr. SHANK. Absolutely. I think that our ability to be able to utilize technologies and create the kind of jobs to create the standard of living that we want is vitally dependent upon our ability to have expertise in manufacturing. I think it's critical.

Mr. THORNTON. Dr. Phillips—excuse me, Dr. White, do you have anything to add?

Dr. ROBERT WHITE. I would just add that it goes the other way as well. Not only does the manufacturing capability support jobs, but you've worked back, and it supports the whole educational process. If you lose manufacturing, you lose engineering, you lose design, you lose science, eventually. So the whole infrastructure is at risk.

Mr. THORNTON. I am so glad that you continued your comments with that point. You may or may not know that before seeking to come to Congress, I was President of the University of Arkansas system, and education is very dear to me. I think it is indeed the base on which all of our competitiveness depends.

Mr. Chairman, I yield back the balance of my time.

Mr. VALENTINE. Thank you, sir.

Let me ask you gentlemen, briefly, these questions.

Do any of you have a feeling that you would like to express to us that there are trade barriers that are a part of the problem—trade restrictions, laws in Japan that have to do with the introduction of American products—is that an area where the Congress and the President should give serious attention in trying to deal with this national dilemma?

Dr. PHILLIPS. Well, sir, it certainly is an area that we have to pay constant attention to. There is no question about it. I think our feeling is that the situation has been improving, but only because we have been requesting for much more reciprocation with respect to openness of markets. I think we still have a way to go with Japan, but there are constant pressures now, and I think that we are looking at these in perhaps more realistic ways than we always have in the past where we, frankly, I think, perhaps largely through our own arrogance, have not paid much attention and felt that these were pinpricks until they got up to be veritable geysers.

It's a terribly important area. The trade people, the State Department and others, I think, are paying attention at this point. We still have inequities. There is no question about it.

Mr. VALENTINE. Do any of you feel that there are changes in the patent laws in this country that could aid the development of American industry in the reasonable transmission of ideas into products, or changes that you would want to supply the subcommittee information on after maybe further reflection on the tax laws—short of just saying, you know, everybody gets a 20 percent decrease? Or, is there a problem to speak the unspeakable, or are there things that we could do about the way labor problems are addressed in this country, and the attitude of organized labor toward

this problem? If there are, realizing that I have gone rather away from your text—

Dr. SHANK. I have one comment to make in that regard. I think that the educational level of our labor force is absolutely key to our competitiveness. I think that that is something that I certainly hope that the Federal Government takes the most serious look at. I think our ability to have a labor force which is skilled and knowledgeable is playing a very important role in our ability to compete with countries like Japan.

Dr. PHILLIPS. I certainly would echo that as well. That's absolutely key to our problems and how we get out of them.

Mr. VALENTINE. Thank you very much for the time invested in the preparation and for coming to share these views with us. We are grateful.

Mr. VALENTINE. The next panel consists of the following: Dr. John A. White, Assistant Director of Engineering, National Science Foundation; Dr. Charles M. Herzfeld, Director of Research and Engineering, Department of Defense; and Dr. Robert M. Simon, Executive Director, Department of Energy.

Welcome, gentlemen. Your prepared remarks will appear in the record, as presented to us. I would ask you to please summarize. The Chair recognizes our first doctor, Dr. John A. White.

## STATEMENT OF DR. JOHN A. WHITE, ASSISTANT DIRECTOR FOR ENGINEERING, NATIONAL SCIENCE FOUNDATION

Dr. JOHN WHITE. Thank you very much, Mr. Chairman. It's good to be with you again. Mr. Thornton, it's good to see you again.

I am mindful of the time. I will be abbreviating, even somewhat, my prepared remarks. We will have for the record fuller treatment in being responsive to your request.

I'm also sure that the Chair appreciated very much my namesake, the other Dr. White's reference, to a basketball team, given the outcome of the recent Final Four activities. I saw you perk up there. I'll try my best to continue that.

Mr. VALENTINE. I was trying to restrain myself.

[Laughter.]

Dr. JOHN WHITE. Well, I saw that. I just applauded that. I knew that Mr. Thornton was sitting there ready to avoid that subject.

Mr. THORNTON. Absolutely, I want to avoid that.

Dr. JOHN WHITE. It's certainly my pleasure to appear before you today and discuss the role of the National Science Foundation in the development of critical technologies, and more specifically to relate our efforts to the National Critical Technologies Panel's report.

Let me state at the outset that the National Science Foundation fully endorses the contents, aims, and objectives of the National Critical Technologies Report.

While some may wish to add to or subtract from the set that is identified in the report, it's been duly noted by the first panel that there is remarkable agreement with the lists of critical technologies developed by very diverse groups, both here and abroad. The consensus, it seems—well, the conclusion is obvious, there is no secret about what the critical technologies are. Essentially, there is

wide-spread agreement that these technologies are the most critical to the Nation's future.

I firmly believe that U.S. can be a world leader in those technologies. I don't think that even those cases where we may be behind that we are so far behind that we can't catch up and move into a leadership position. I also believe that private industry bears the primary responsibility in this regard, but there is also a very important role for the Federal Government in sharing that leadership.

Let me now turn, very quickly, to the role of the National Science Foundation in supporting critical technologies. As you know, NSF plays an important role in Federal efforts to maintain and strengthen the Nation's knowledge base and to develop new generations of scientists and engineers. I was particularly pleased in reading the report to see that the panel reaffirmed the need for continued strong support for basic scientific research across many fields. The report states, and I quote, "Support for the basic sciences needs to be broadly based in order to maximize the yield of useful advances that ultimately can be translated into technologies."

As you know, a large fraction of NSF's budget supports the fundamental long-term research in the basic sciences, engineering and mathematics, that ultimately makes possible advances in specific technologies. I must also point out that NSF's research support includes support of individual investigators, multiple investor groups, research centers, and national user facilities. The research is university-based, and often includes significant interaction with industry. Our Engineering Research Centers being an example with which you are quite familiar with, Mr. Chairman.

I was also pleased to see that the panel noted "the importance of science and mathematics education to the Nation's ability to remain a world leader in technology and technology applications." This is a point which Mr. Thornton picked up on and it was certainly supported by the first panel.

In addition to contributing to the knowledge base for science and technology, research contributes to educating those involved—undergraduate and graduate students, post- doctoral associates, and faculty engaged in research become better educated thereby. This educational component should not be overlooked or minimized, for it's an important mechanism by which we provide the human resources necessary for future advances in research in technology.

Improving science and mathematics education and providing broad support for basic scientific research are the core responsibilities of the National Science Foundation. However, our role with respect to supporting the development of the critical technologies does not end there, although the research supported by NSF is generic and long term, in the past few years, there has been increasing emphasis on supporting research related to important technologies. Some examples include our supporting research on superconductivity, biotechnology, materials synthesis and processing.

Another area supported by NSF is the computational infrastructure for research. This supports both the super computer centers and other computational activities so that we can carry out com-

plex computations, simulation, and modeling necessary for many of the critical technologies.

Now, let me cite some specific examples where NSF supports technologies identified in the report. In fiscal year 1991, NSF will spend approximately $60 million on semi- conductor research, $129 million on biotechnology, $19 million on robotics, $59 million on the synthesis and processing materials, and $169 million on high performance computing. In addition, NSF will spend about $59 million on research to develop and expand the engineering foundations of manufacturing across a broad spectrum of American industry.

Rather than attempt to detail all of NSF's research and related activities in support of the critical technologies, I want to focus today on just one element which you are quite familiar. That is our research centers. In general, our centers represent relatively large cross-disciplinary efforts, often focused on technology development and involving extensive collaboration with industry. Among the centers supported by NSF, those which in my judgement have a significant technology advance are engineering research centers, are science and technology centers and the smaller— but more important perhaps in some regards, because of their ability to move quickly into emerging areas of technology— would be your industry/university cooperative research centers.

Let me briefly describe those. The Engineering Research Centers Program was established to support cross-disciplinary engineering centers focusing on research and education in major technological areas important to U.S. industrial competitiveness. The Science and Technologies Centers Program encourages university-government-private sector collaborations to develop a knowledge base in science and technology that will contribute to the economic and educational competitiveness of the U.S. The STCs, as they are called, provide a mechanism to exploit opportunities in science and engineering, where the complexity of the research problems requires the advantages of scale, duration facilities, or collaborative relationships.

Our smaller Industry/University Cooperative Research Centers encourage industry/university cooperation by developing research programs defined by the industries supporting each center. I might add that I came to the National Science Foundation from having served as the Director of one of the IUCRCs at Georgia Tech. In particular, I've been affected greatly from the experience of the IUCRC at N.C. State. I know that it certainly has had significant impact, with the focus there of that university in the areas of electronics.

It then led to N.C. State receiving an Engineering Research Center in the area of electronics. It has certainly leveraged off of, I think, the capabilities exhibited through the SRC. So I think you can see how these things work together.

Since NSF's support ends after five years in our IUCRSs, we have a very important incentive there to improve collaboration with industry to ensure that the research meets industrial needs. On the average, those centers attract about ten times the support provided by NSF, through contributions from industrial firms in several states.

There are currently 45 centers carrying out research in a variety of areas related to the critical technologies, including polymeric and glass processing, plastics recycling, non-destructive evaluation, chemical process control, sensors and actuators, computer graphics and software engineering, codings, grindings, and quality control measurement.

It's interesting when I looked at the list of the 22 technologies and the Critical Technologies Report, and I compared those to the focus of our 45 IUCRCs, our 19 Engineering Research Centers, and our 25 Science and Technology Centers, I found that practically all of the 45 industry/university cooperative research centers were focused on one of the 25 areas identified in the report. All of the ERCs did, and 80 percent of the STCs focused on more or more of the 22 critical technologies.

Take materials, as an example, we have five Engineering Research Centers and eight Science and Technology Centers focused in the area of materials, including the University of Wisconsin in Plasma-Aided Manufacturing; N.C. State and other North Carolina institutions' collaboration in the Advanced Electronic Materials Processing area; Virginia Tech's High Performance Polymeric Adhesives and Composites center; and the University of California at Santa Barbara's Center on Quantized Electronic Structures.

I might also add that in the materials area, the University of Texas at Austin's focus on Synthesis, Growth, and Analysis of Electronic Materials is certainly appropriate, given the location of MCC and Sematech, and the capabilities there in the Austin area.

In the area of manufacturing, we have four Engineering Research Centers, including those at Ohio State in Net Shape Manufacturing; and at Purdue in Intelligent Manufacturing Systems.

In the area of information and communication technologies touched on by Chairman Brown and Mr. Thornton, we have four ERCs and five STCs focused in that area, including one on Data Storage Systems at Carnegie-Mellon; one on Optical Computing Systems at University of Colorado, also involving Colorado State University; and at the University of Utah in Computer Graphics and Scientific Visualization. I might add that the new STC and Ultrafast Optical Science at the University of Michigan would also be included in this list.

Turning to the biotechnology and the medical technology area, we have three Engineering Research Centers and five STCs in this area, including one which you are familiar with, Duke, in the Emerging Cardiovascular Technologies area; at MIT in Biotechnology Process Engineering; at Cal. Tech in Integrated Protein and Nucleic Acid Biotechnology; and at the University of Illinois in Magnetic Resonance Technology.

In the area of energy and the environment, we have four Engineering Research Centers, and two STCs, including one at Lehigh in Advanced Technology for Large Structural Systems; and at Michigan State in Microbial Ecology.

In conclusion, Mr. Chairman, I can assure you that NSF will continue to work with OSTP and the other Federal agencies to ensure that the technologies identified in the report are adequately supported, consistent with the principles of the published report by OSTP entitled, "U.S. Technology Policy."

I might add FCCSET, the Federal Coordinating Council for Science, Engineering, and Technology, the committee specifically on industry and technology headed by Dr. Robert White, provides a very convenient mechanism for this coordination.

As we enter the 21st century, the Nation's well being and quality of life will depend increasingly upon maintaining superior technology, including the development of the technical knowledge base, the physical infrastructure, and the human resources pool. In my judgment, if the U.S. is to fulfill this goal, a long-term commitment of support is needed for the critical technologies identified in the report.

Mr. Chairman, thank you for the opportunity to appear before you today.

Mr. VALENTINE. Thank you, sir.

[The prepared statement of Dr. John White follows:]

TESTIMONY OF
DR. JOHN A. WHITE
ASSISTANT DIRECTOR FOR ENGINEERING
NATIONAL SCIENCE FOUNDATION

BEFORE THE SUBCOMMITTEE ON TECHNOLOGY
AND COMPETITIVENESS

NSF'S ROLE IN THE DEVELOPMENT OF CRITICAL TECHNOLOGIES

APRIL 25, 1991

INTRODUCTION

It is my pleasure to appear before you today to discuss the role of the National Science Foundation in the development of critical technologies. As you know, the National Critical Technologies Panel recently published its long-awaited critical technologies report. The report identified twenty-two technologies deemed critical to the Nation's economic prosperity and national security. The selection of national critical technologies was carried out by a panel appointed by the Director, OSTP, of which Dr. Frederick M. Bernthal, Deputy Director of NSF, was a member.

First let me state the NSF fully endorses the contents, aims and objectives of the National Critical Technologies Report. While some may wish to add or subtract from the set identified in the report, it should be noted that there is remarkable agreement with lists of critical technologies developed by very diverse groups from around the world. Essentially there is widespread agreement that these technologies are the most "critical" to the Nation's future.

I firmly believe the U.S. can be a world leader in the critical technologies. Private industry bears primary responsibility, but there is an important role for the Federal Government in sharing the leadership.

Consider a White House publication, "U.S. Technology Policy" issued last fall. In it, Dr. D. Allan Bromley wrote that one of the federal government's responsibilities is "to participate with the private sector in precompetitive research on generic, enabling technologies that have the potential to contribute to a broad range of government and commercial applications."

Other reports have also stressed the need to expand support for critical technologies, e.g. the Council on Competitiveness report, *Gaining New Ground*; the NRC report, *Maintaining Competitiveness in the Age of Materials*; the President's Council on Competitiveness *Report on National Biotechnology Policy*, and the OSTP report, *Grand Challenges in High Performance Computing and Communications*.

NSF ROLE

Now let me turn to the NSF role in supporting the critical technologies identified in the report. As you know, NSF plays an important role in Federal efforts to maintain and strengthen the Nation's knowledge base and develop new generations of scientists and engineers. Further, a large fraction of NSF's budget supports the fundamental long term research in the basic sciences, engineering, and mathematics, such as physics, chemistry, biology and geology, that ultimately makes possible advances in specific technologies.

NSF's research support includes support of individual investigators, multi-investigator groups, research centers and national user facilities. The research is university-based, and often includes significant interaction with industry, e.g. our Engineering Research Centers. Although the research supported by NSF is generic and long-term, and is not product-specific, in the past few years there has been an increasing emphasis on supporting research related to important technologies, e.g. superconductivity, biotechnology, materials synthesis and processing.

In addition to contributing to the knowledge base for science and technology, university-based research has a strong educational component, through the involvement of undergraduate and graduate students, as well as postdoctoral associates. This educational component should not be overlooked or minimized, for it is an important mechanism by which we provide the human resources necessary for future advances in research.

Another area supported by NSF is the computational infrastructure for research. This support provides investigators with the facilities to carry out complex computations, simulation and modeling necessary for many of the critical technologies.

NSF ACTION RELATED TO CRITICAL TECHNOLOGIES

Now let me cite some specific examples where NSF supports technologies identified in the OSTP report. In FY 1991 NSF will spend approximately $60 million on semiconductor research; $129 million on biotechnology; $19 million on robotics; $59 million on the synthesis and processing of materials; and $169 million on high performance computing. In addition, NSF will spend about $59 million on research to develop and expand the engineering foundations of manufacturing across a broad spectrum of American industry.

Rather than attempt to detail all of NSF's research and related activities in support of the critical technologies, let me focus today on one element with which I am most familiar - NSF's research centers. In general, our centers represent relatively large cross-disciplinary efforts, often focused on technology development and involving extensive collaboration with industry. Among the centers supported by NSF, the following are examples of those having technology advancement as explicit components of their research mission: Engineering Research Centers; Science and Technology Centers; and the Industry/University Cooperative Research Centers. Let me briefly describe these centers.

The **Engineering Research Centers (ERC)** Program was established to support cross-disciplinary engineering centers focusing on research and education in major technological areas important to U.S. industrial competitiveness. The centers support cross-disciplinary teams of faculty and students, provide for large-scale experimental equipment, and bring an integrated, engineering systems perspective to engineering research. They improve the relevance of engineering education to engineering practice by providing students with experience in research driven by technological and industrial views, exposure to work in cross-disciplinary teams, and direct contact with industrial personnel.

The **Science and Technology Centers (STC)** Program encourages university--government-private sector collaborations to develop a knowledge base in science and technology that will contribute to the economic and educational competitiveness of the U.S. The STCs provide a mechanism to exploit opportunities in science and engineering where the complexity of the research problems requires the advantages of scale, duration, facilities, or collaborative relationships. The centers involve students, research scientists, and engineers from academia, nonprofit organizations, industry and Federal laboratories to stimulate opportunities for the transfer of knowledge.

The **Industry/University Cooperative Research Centers (I/UCRC)** Program encourages industry/university cooperation by developing research programs defined by the industries supporting each center. Students and faculty interact with industrial personnel to improve the relevance of the work to industry and to accomplish technology transfer. Since NSF support ends after five years, an important incentive exists to improve collaboration with industry and to ensure that the research meets industrial needs. On average, the centers attract ten times the support provided by NSF through contributions from firms and several states. There are currently 45 centers carrying out research in a variety of areas relating to the critical technologies, including polymer and glass processing; plastics recycling; nondestructive evaluation; chemical process control; sensors and actuators; computer graphics and software engineering; coatings; grinding; and quality control measurement.

Below is a list of the major ERCs and STCs that are working to advance the frontiers of knowledge in the broad technology areas highlighted in the OSTP report.

**MATERIALS**

University of Minnesota -- Interfacial Engineering (ERC)

University of Wisconsin/University of Minnesota -- Plasma-Aided Manufacturing (ERC)

University of Colorado/Colorado State University -- Optical Computing Systems (ERC)

University of Illinois/Urbana -- Compound Semiconductor Microelectronics (ERC)

North Carolina State University/other North Carolina institutions -- Advanced Electronic Materials Processing (ERC)

Kent State University -- Advanced Liquid Crystalline Optical Materials (STC)

University of Illinois -- Superconductivity (STC)

Virginia Polytechnic Institute -- High Performance Polymeric Adhesives and Composites (STC)

SUNY, Stony Brook -- High-Pressure Research (STC)

University of Rochester -- Photoinduced Charge Transfer (STC)
University of Cal. (Santa Barbara) -- Quantized Electronic Structures (STC)

Northwestern University -- Advanced Cement-Based Materials (STC)

Univ. of Texas (Austin) -- Synthesis, Growth and Analysis of Electronic Materials (STC)

**MANUFACTURING**

Carnegie-Mellon University-- Engineering Design (ERC)

University of Maryland/Harvard University -- Systems Research (ERC)

Ohio State University -- Net Shape Manufacturing (ERC)

Purdue University -- Intelligent Manufacturing Systems (ERC)

**INFORMATION AND COMMUNICATIONS TECHNOLOGIES**

Mississippi State University -- Computational Field Simulation (ERC)

Columbia University -- Telecommunications Research (ERC)

Carnegie-Mellon University -- Data Storage Systems (ERC)

University of Colorado/Colorado State University -- Optical Computing Systems (ERC)

Rutgers University -- Discrete Mathematics and Theoretical Computer Science (STC)

University of Utah -- Computer Graphics and Scientific Visualization (STC)

Rice University -- Parallel Computation (STC)

University of Minnesota -- Computation and Visualization of Geometric Structures (STC)

University of Michigan -- Ultrafast Optical Science (STC)

**BIOTECHNOLOGY AND MEDICAL TECHNOLOGY**

Duke University/other North Carolina institutions -- Emerging Cardiovascular Technologies (erc)

Massachusetts Institute of Technology -- Biotechnology Process Engineering (ERC)

Montana State University -- Interfacial Microbial Processes (ERC)

University of Virginia -- Biological Timing (STC)

Univ. of Cal. (Davis) -- Engineering Plants for Resistance Against Pathogens (STC)

California Institute of Technology -- Integrated Protein and Nucleic Acid Biotechnology (STC)

University of Illinois -- Magnetic Resonance Technology (STC)

Carnegie Mellon Univ. -- Light Microsçope Imaging and Biotechnology (STC)

**ENERGY AND THE ENVIRONMENT**

Brigham Young University/University of Utah -- Advanced Combustion Technology (ERC)

University of California, Los Angeles -- Hazardous Substance Control (ERC)

Texas A&M University/University of Texas at Austin -- Offshore Technology (ERC)

Lehigh University -- Advanced Technology for Large Structural Systems (ERC)

Michigan State Univ. -- Microbial Ecology (STC)

University of Chicago -- Clouds, Chemistry and Climate (STC)

CONCLUSION

In conclusion, I can assure you that NSF will work with OSTP and the other Federal agencies to ensure that the technologies identified in the report are adequately supported, consistent with the principles of the U.S. Technology Policy. The Federal Coordinating Council for Science, Engineering and Technology (FCCSET) Committee on Industry and Technology (CIT) provides a convenient mechanism for this coordination.

As we enter the 21st century, the Nation's well being and quality of life will depend increasingly upon maintaining superior technology, including the development of the technical knowledge base, the physical infrastructure and the human resources pool. In my judgement, if the U.S. is to fulfill this goal, a long-term commitment of support is needed for the critical technologies identified in the OSTP report.

Mr. Chairman, thank you for the opportunity to appear before you today.

Mr. VALENTINE. Dr. Herzfeld?

**STATEMENT OF THE HONORABLE CHARLES M. HERZFELD, DIRECTOR, RESEARCH & ENGINEERING, DEPARTMENT OF DEFENSE**

Dr. HERZFELD. Mr. Chairman and Members of the Committee, ladies and gentlemen, it's a pleasure to be here again to appear before you. I'm pleased to be here this afternoon to support the report on the National Critical Technologies by the panel that Dr. Phillips chaired, and to discuss, briefly, or as much as you would like, however, its relationship to the Defense Critical Technologies Plan.

I'm honored to be a member of the National Critical Technologies Panel, and I wish to thank Dr. Phillips for his distinguished leadership.

My staff and I personally participated on the panels that produced the report, and we believe that the technologies listed in the report and in the Defense Critical Technologies Plan are very much in consonance with each other and that their objectives are quite supportive of each other. We are comfortable with how they fit together and believe that both lists, along with other critical technology lists, are useful in putting the spotlight on the problems that we have.

But, most importantly, these plans are a guide to action. In the DOD, we have redirected significant resources into the critical technologies and away from lower priority programs.

Let me answer very briefly, the four questions you put before us. What do we mean by critical? In our case, that means the critical technologies are those that we must develop further and rapidly in order to be able to field superior military systems. That is how we define our list.

You asked, is this a normal situation? To that, in defense, we say, yes, unfortunately, it is. It has always been that way and, presumably, it will always be that way unless total peace breaks out. We have had the challenge of building for our national defense, and have done it in this particular way for a very long time. We are pleased that we seem to have been doing the right things.

There is a different dimension that needs to be highlighted, and it was highlighted by others in the first panel. In the past, U.S. defense technology, more or less, drove the countrywide technology. It was the biggest contributor to the country's technology. This is no longer so. Defense technology is a relatively minor part of the total picture. It is still at the leading edge in a number of areas and we must keep it that way. But, overall, most of the technology that is developed in this country is developed by the civilian sector for the civilian sector, and most of the science is supported by, not the Defense Department, but the National Science Foundation, the Department of Energy, and others.

When I was a graduate student in the late 1940s, I had an office in the Naval Research Laboratory, a research assistantship. That was the only way to get money for research in those days, either from the Atomic Energy Project or from the Navy. Those days are

long gone and, of course, the appearance of NSF made a major difference. It really changed the landscape completely.

The next question has to do with critical technologies and suggesting a course of action. We agree with that in the Defense Department. Our Defense Critical Technologies Plan is not only a strategy, but it's also an action plan. We will introduce this plan publicly shortly. There is a hearing scheduled for early May in the other House—the other body, as I'm told it is called, on the critical technologies, and we will be available for you, of course, anytime you wish to hear from us on that subject in more detail.

We have laid down a series of technical objectives for each of our critical technologies, for a ten to fifteen year timespan—and in some cases longer. We have identified the budget numbers that are set aside against each of these technologies for the six year Defense Budget Plan, and we have, as I said, shifted some significant resources into the key technologies, into critical technologies.

In addition, we participated rather heavily with the FCCSET high performance computing and communications initiative and are very happy to do so because the overlap there is really tight with civilian technologies.

The last question is, of course, the most important for us in a sense. It says, is it appropriate for the DOD to totally fund multi-use technology development needed for defense? We have to say in part, because of what I said a moment ago. We cannot fund all or most of the multi-use technologies, although, indeed, most of those technologies that we do fund are multi-use. We have no inhibition at all about doing that, contrary to some statements by various people. We have no problem with multi-use technologies, provided we fund those parts of them that are needed for the defense posture. If these programs have spin-off for civilian technology, that is all to the good and we are very pleased to have that happen.

We should note that the question came up in discussion with the first panel that we are strong believers in the pre-competitive phase, multi-company consortia. We are, indeed, the ones who fund SEMATECH, which you discussed a number of times, and are very pleased to have this going on there. DARPA has just started five consortia on varied subjects that are multi-corporational and that attack different critical technology areas.

With that, I think I would like to stop now. I will be, of course, available for any questions.

Thank you.

[The prepared statement of Dr. Herzfeld follows:]

Hold Until Released
By The Committee

DEPARTMENT OF DEFENSE

STATEMENT ON CRITICAL TECHNOLOGIES

BY

DR. CHARLES M. HERZFELD
DIRECTOR DEFENSE RESEARCH AND ENGINEERING

TO THE

SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT
COMMITTEE ON ARMED SERVICES

AND THE

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS
SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE

OF THE

UNITED STATES HOUSE OF REPRESENTATIVES

APRIL 25, 1991

DEPARTMENT OF DEFENSE
STATEMENT BY THE
DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
TO THE
SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT
OF THE COMMITTEE ON ARMED SERVICES
AND THE
SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS
OF THE SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE
UNITED STATES HOUSE OF REPRESENTATIVES

Mr. Dellums, Mr. Valentine, members of the Committees, ladies and gentlemen. I'm pleased to be here this afternoon to discuss the Report of the National Critical Technologies Panel and its relationship to the Defense Critical Technologies Plan.

My staff and I personally participated on the panels that produced the Office of Science and Technology Policy (OSTP) report. I believe the technologies listed in the Defense Critical Technologies Plan and the OSTP report to be very much in consonance with each other, and their objectives are quite supportive of each other. I am very comfortable with how they fit together and believe that both lists, along with other critical technologies lists (those of the Services, of the Joint Chiefs, of the Defense Science Board, and of the Department of Commerce) are useful in putting the spotlight on the technology base of our nation, the direction it needs to go in, and its overall health.

I would be pleased to answer your questions.

Mr. VALENTINE. Thank you very much.
Dr. Simon?

**STATEMENT OF DR. ROBERT M. SIMON, EXECUTIVE DIRECTOR, DEPARTMENT OF ENERGY**

Dr. SIMON. Mr. Chairman and members of the subcommittee, I am pleased to be here this afternoon to represent the Department of Energy and, to add our Department's full concurrence and support to the Report on the National Critical Technologies. The DOE was an enthusiastic participant in that panel. Under Secretary John Tuck was our representative.

The DOE is also an enthusiastic participant in some of the other efforts that you have heard about this afternoon: the FCCSET committees that deal with high performance computing, the upcoming efforts dealing with materials, and with advanced manufacturing.

As you can see in my prepared statement, DOE has some major R&D investments in many of the areas identified in the critical technologies report: supercomputing, biotechnology materials, and the surface transportation area. DOE is also moving out in a policy sense on what has been identified this afternoon as sort of the next issue in the debate. That is, how to take a list and go somewhere with it. There is major focus within DOE that's been underway for some time. It's continuing in helping our laboratories and facilities become better partners in technology initiatives with U.S. industry.

Congress has helped us by giving us some tools in the form of the National Competitiveness Tech Transfer Act of 1989, which opened up a new avenue to our government owned contractor operated laboratories to use CRADAs, Cooperative Research and Development Agreements. We have been modifying the contracts for our GOCO laboratories.

On March 20 of this year, we signed the first CRADA between Los Alamos National Laboratory and a private sector firm, Life Technologies, Incorporated. It addressed in the human genome area one of the areas identified in the critical technologies report, that being, recombinant DNA technology. Los Alamos' contribution to the party was to being a patent on labelling technology for DNA segments and some instrumentation expertise. Life Technologies, Incorporated brought enzymology expertise and expertise in nucleic acid chemistry. We see this as only the first in a long series of CRADAs that we hope our laboratories will be negotiating with private industry.

Another example of where DOE and industry partnership in a critical technology are focusing on pre-competitive research is the U.S. Automobile Battery Consortium. This consortium is bringing together the three major automobile manufacturers: GM, Ford, and Chrysler, along with the electric power industry. We anticipate that they will bring significant participation from the electric power industry, and co-funding will come from DOE to accelerate the market potential of electric vehicles by jointly researching and identifying those promising advanced battery alternatives, and by developing electrical energy systems that will provide electric vehicles with the range and performance that will be competitive with current gasoline-based vehicles. In general, this could pool funding

for the high risk, high pay-off, and high-cost of advanced battery research and development for electric vehicles.

The partnership agreement between the three major auto companies was signed on January 30 of this year. I think that it would be fair to say that those participants think of this as being a major milestone in their effects to bring electric vehicles to market. DOE, of course, is putting in for some money in this, as part of the President's fiscal year 1992 budget request.

I think that those are some examples. I think that DOE has a continuing commitment to explore other kinds of partnership arrangements with private industry, capitalizing and utilizing the expertise in our national laboratories.

With that, I think I'll conclude my statement and answer any questions you may have.

[The prepared statement of Dr. Simon follows:]

STATEMENT OF

DR. ROBERT M. SIMON

EXECUTIVE DIRECTOR

SECRETARY OF ENERGY ADVISORY BOARD

U.S. DEPARTMENT OF ENERGY

BEFORE THE

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
AND
THE SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT
COMMITTEE ON ARMED SERVICES

OF THE

UNITED STATES HOUSE OF REPRESENTATIVES

APRIL 25, 1991

STATEMENT OF DR. ROBERT M. SIMON,
EXECUTIVE DIRECTOR
SECRETARY OF ENERGY ADVISORY BOARD
U.S. DEPARTMENT OF ENERGY
REPORT OF THE NATIONAL CRITICAL TECHNOLOGIES PANEL
APRIL 25, 1991

Good afternoon. My name is Robert M. Simon, and I am the Executive Director of the Secretary of Energy Advisory Board of the U.S. Department of Energy. As part of the responsibilities of my position, I help coordinate DOE participation in interagency efforts to define scientific and technical priorities, including interagency committees sponsored under the aegis of the Office of Science and Technology Policy. Thus, I am pleased to be here today to discuss the Report of the National Critical Technologies Panel, focusing on the two basic areas outlined in your letter of invitation to the Department:

(1) the overall DOE reaction to the report; and

(2) the role of the DOE and its National Laboratories in the process of developing U.S. capabilities in critical technologies.

DOE Reaction to the Report of the National Critical Technologies Panel

The Department of Energy was a member of the National Critical Technologies Panel. Under Secretary John C. Tuck represented the Department, with support from myself and other DOE staff in Headquarters and with input from the scientific and technical staffs at the DOE National Laboratories. The Department was pleased to be a member agency on the panel and fully supports the conclusions of the report. The Department will use the report as an

important input in future program and budget planning, along with other key Administration policies such as the National Energy Strategy.

The Role of the DOE and Its National Laboratories in Critical Technologies

The list of National Critical Technologies includes many areas where the Department of Energy plays an important role within the Federal government. Several examples of these areas include:

- Energy and Environment. DOE has the lead responsibility in the Federal government for critical technologies in energy conservation, renewable energy, and energy storage. Our activities in these areas are currently being supported under the DOE Assistant Secretary for Conservation and Renewable Energy (over $500 million in the President's FY 1992 budget request), with additional support from research funded by the DOE Office of Energy Research.

- Materials. DOE is the largest single source of Federal funds for research in materials science and engineering, with a FY 1990 budget of $506 million out of a total Federal effort of $1.4 billion. DOE's civilian and defense-oriented programs cover topics in critical technology areas of materials synthesis and processing, ceramics, composites, and high-performance metals and alloys.

- Information and Communication. DOE plays a key role in the Federal government's efforts in high-performance computing and communications. The

DOE supports the Nation's largest collection of parallel computers (15) as well as the Nation's largest number of Cray-class supercomputers (26) at its Laboratories. Scientists and engineers at the DOE National Laboratories are at the leading edge in advanced software for parallel computer architectures. For example, Sandia scientists won the 1988 Gordon Bell prize for creating the fastest parallel supercomputer code, and scientists at Oak Ridge National Laboratory were recently recognized for achieving the fastest price/performance ratio for a real application on a parallel computer.

▪ Biotechnology and Life Sciences. In the President's FY 1992 budget request, DOE is slated to become the Federal government's second-largest funder of biotechnology research, at $140 million. This represents a 27 percent increase over the level enacted for the FY 1991 DOE budget. One of the most significant endeavors in this area is the Human Genome Program, supported by the Departments of Health and Human Services and Energy. DOE also contributes to the development of medical technologies. The development and application of positron emission tomography (PET), one of the medical technologies identified in the Report, owes much to research funded by the Department.

▪ Aeronautics and Surface Transportation. Among the critical surface transportation technologies identified in the Report are advanced batteries and fuel cells. The DOE plays a leading role within the Federal government in supporting these technologies, and is working closely with the U.S. automobile industry to advance the state of the art.

The Report of the National Critical Technologies Panel identifies deployment of critical technologies as a key to future U.S. competitive success. The Department of Energy is taking an increasingly active role in facilitating the transfer, to the U.S. private sector, of the technologies developed with its funds. Congress has provided stimulus to this effort through the passage of legislation such as the National Competitive Technology Transfer Act of 1989. The Secretary of Energy, Admiral James D. Watkins, has recently promulgated a Department-wide Notice on "Setting the Course for Technology Transfer at the Department of Energy" that identifies missions, goals, strategies, and responsibilities for enhancing technology transfer within the DOE. Some recent accomplishments of the Department include the following:

- On March 20, 1991, with DOE approval, a Cooperative Research and Development Agreement (CRADA) was signed between the Los Alamos National Laboratory and private industry in the area of human genome research. Technology transfer from DOE Laboratories through such CRADAs is one way in which the goals expressed in the Report can be achieved.

- Another innovative example of a DOE-industry partnership to carry out precompetitive research on a critical technology identified in the Report is the U.S. Automobile Battery Consortium. This consortium, formed by the U.S. automobile industry and which is expected to include significant participation from the electric power industry, was the result of DOE efforts to identify the most promising battery alternatives. The goals of the consortium are to:

- Accelerate the market potential of electric vehicles by jointly researching the most promising advanced battery alternatives;

- Develop electrical energy systems capable of providing electric vehicles with range and performance competitive to petroleum-based vehicles; and

- Pool funding for high-risk, high-cost advanced battery research and development for electric vehicles.

A partnership agreement was signed by Ford, General Motors, and Chrysler on January 30 to conduct a major multi-year research and development effort to develop advanced batteries. The participants consider this agreement to be a major milestone in their efforts to bring electric vehicles to market and regain an international competitive edge. The consortium plans to propose a cost-shared program to DOE, with 50 percent of the funding to be provided by the automobile, utility, and battery industries. In the President's FY 1992 budget request for DOE, $27 million is sought for this initiative.

This is not an exhaustive list of DOE technology-related initiatives. The Department will continue to explore other partnership arrangements--with industry, universities, and its own National Laboratories--to advance critical technologies, consistent with the law and the Administration's technology policy.

This concludes my formal statement. I would be happy to answer any questions you have.

Mr. VALENTINE. Thank you, Dr. Simon.

Dr. White, how do the needs of industry for critical technologies—how do these needs get factored into NSF's decision on which research areas to fund?

Dr. JOHN WHITE. I think you know that the areas that we fund are very much based on, in a sense, a bottoms-up approach. We've got a lot of input from industry through our advisory committee. As an example, on my advisory committee, I have 30 percent, I think, or more that are from industry or a wide range of industry. Most of our panels have a very high participation of industry. In fact, we have a number of visiting engineers and scientists that come to the Foundation from industry to spend time with us as program officers. Then, additionally, as reviewers, we have them participate.

We often turn to the National Research Council for advice about areas for us to focus on. Again, their particular panels and committees include a high industry participation.

I think those are the most significant ways. Of course, as you know, we receive a number of visits from people from industry, as well as associations, raising our consciousness, if you will, about areas needing attention. Just as they get your attention, Mr. Chair, they also get ours.

I'll not forget the visit by one industry executive who basically said, "We're prepared to put $5 million into an area if we can see NSF supporting it." I might add that, in this particular case, we were not influenced by that so much. It turned out that an independent panel ended up recommending funding, and it did. By the way, he was not forthcoming with his $5 million. But, nevertheless, we did get very direct input from an industry executive about the importance of that area.

Mr. VALENTINE. Dr. White, are you able to give the subcommittee an approximate figure as to the percentage of your appropriation which would be targeted for research, as to the percentage which would be targeted towards developing the capacity to manufacture or the capacity to sell?

Dr. JOHN WHITE. I'd be happy to do that for the record. I think that that's too important a question for me to give you a response off the top of my head, Mr. Chair.

Mr. VALENTINE. If you would, we would appreciate it, with as much detail as possible. I don't know, maybe it's personal frustration, but in my personal world, as a member of this institution, I do experience a certain feeling of frustration, I must confess, which is probably evident every time I get into one of these things that we seem so often to have business on, with all the other things that confront us. I know there are problems, but they seem to be saying, well, now you helped us invent it, now tell us how to sell it. I have just felt that that was not necessary for the government to do that. I thought that was an area where we out did everybody else. But, I'm sure we'll return to that.

[The information follows:]

In FY 1990 NSF's Engineering Activity (ENG) obligated about $55 million for R&D and expand the engineering foundations of manufacturing across a broad spectrum of American industry. This amounts to about 27.5% of the ENG FY 1990 budget.

Mr. VALENTINE. Dr. Herzfeld, it seemed to me that I saw a little glow on your countenance when I was ruining Mike Wallace's day earlier in this section by expressing some general displeasure with the calibre of his television program, other than as a show- biz thing. But, what do you say about what I think is the— I would use the term, perhaps, indictment—of American capacity to manufacture sophisticated machines of sophisticated warfare? What do you say to the charge that if we are confronted with a situation like the Persian Gulf War 15 years from now—and I understood him to say this—we will not have that capability that is from all our own shores? We might be able to buy it, if we can find somebody to sell it to us, and that even today, it would not have worked without significant purchases from foreign manufacturers which were of materials that were not available in the United States.

What do you say about that?

Dr. HERZFELD. It's very a important question, Mr. Chairman. Of course, we have struggled with it and will continue to struggle, I suspect, for a long time.

I did not see the program. I've made it a practice never to comment on things that I haven't seen or read. So I'd rather not comment on the program itself. But, the question stands on its own two feet, obviously, and deserves to be taken up that way.

Mr. VALENTINE. If you can equate it with that or otherwise, if you would write me a little personal letter, because I want to be able to sleep a little bit better at night.

Dr. HERZFELD. I think you should not let this keep you awake. I think that other things are much more urgent.

Mr. VALENTINE. I feel reassured already.

Dr. HERZFELD. Quite seriously, for a moment, I think our difficulties with getting patient investors—tacking on to the questions that were posed earlier, is a much more serious problem. If you would like, I can get—

Mr. VALENTINE. And that is a real problem, isn't it? An instant gratification—you can invest your money, you get a little turnover, you make a profit now. Why gamble on something that might or might not be there 10 years from now?

Dr. HERZFELD. Yes. I think that is much more fundamental. But, it bears on the question that you asked me now. So let's count it to that. But, I do want to address, specifically, what you asked about.

There will be critical parts, in the future, that we must be able to make in our country, and they must be the best in the world. There are certain kinds of computers, certain kinds of sensors, there are jet engines, there are guns, missiles, wars—a whole bunch of things. We do not want to buy our torpedoes from somebody. We want to have our own torpedoes. I just want to be very clear, about that. That's just an example, you understand.

Now our job in the Department is to put together a critical technologies strategy that will assure the availability of the technologies in the U.S., these critical technologies—that's what we mean by critical—and to buy sufficient copies of each item so that we have an adequate defense industrial base. That's our challenge in the Department. We take it very seriously. It is being addressed by many people in the Department, from the Secretary on down.

The Secretary has said a number of times—and I believe he is correct—that we will be able to mount an operation such as the one we did earlier this year, in the future. But, I think that was just as much a setting of objectives as it was a prediction. We will just make darn sure that we can, and he is being very emphatic about that. I am, obviously, a member of the team, trying to do my part of that job.

How much, in fact, of foreign technology is used by American systems is something that is being studied and analyzed, and I will not give you an off-the-top answer. As best we can tell, it was not very much, but that is a very tentative answer. When we have firm data—just as with all the lessons learned—when we have firm data and have analyzed it, maybe we'll be back at the Congress, and we'll explain what we've found. As a matter of policy of the Department, we do not wish to go on the basis of any non-final information. It's just a terribly serious matter.

But let me make a philosophical point, which I made earlier in the week before your sister committee that is represented here. And this is, in fact, the joint hearing of both. I was asked the same question by a member of the House Research and Development Subcommittee, and I gave the following answer for the long run. It depends on what view you have of the future, in terms of free trade.

My view of the future says it is best for this country, and the world as a whole, to have really quite free trade with a minimum of barriers. There will be some. We will not be wanting to export strategically important materials to certain countries, obviously. We will not want to give the most precious military technology away, obviously. But on everything else, this is probably in everybody's best interest for reasonable trade. We should have government policies that will make a viable industrial base in this country. As Mr. Ritter pointed out, there is some good news, as well as Dr. Phillips and Dr. White.

If that's the case, my advice to all of us is, let's make sure we have enough alternative sources for everything we must have. It is not different from a company like an automobile company that buys 30 percent of its parts. It does not make them. It has to make sure that it can get these parts if one of its suppliers fails or has an accident, explosion, fire, or goes out of business. The way you do that is, you line up alternate sources, and how many, what kind, and how big they are. It depends on what the circumstances are.

That's what a prudent businessman does, and that's what a prudent country should do. That's how I think we should strategize this particular part of your large and complex question.

Mr. VALENTINE. An example tnat has, I suppose, nothing to do with high tech and the type of matters that we are talking about here—but one example that is cited when we struggle with what some say are our parochial interests and having to do with textile industry in this country, and that sort of thing, you hear this. As I say again, it is not high tech. But, we cannot now, in this country, produce the shoes to put on the feet of the people who defend the Nation. We have to go overseas to buy the combat boots, don't we?

Dr. HERZFELD. I think that is true for some. I don't know how uniform that is. I'm not an expert on that.

Mr. VALENTINE. Dr. Simon, the DOE National Labs are, of course, a national resource. I would go so far as to say that they are national treasures. I think that it is fair to say perhaps that their mission is changing. What do you envision as the contribution that these organizations can make to the development of the technologies that we are here talking about and the transfer of these technologies to U.S. companies?

Dr. SIMON. Well, Mr. Chairman, I believe that it's fair to say that the laboratories—DOE laboratories as well as laboratories that belong to other agencies, such as the DOD laboratories and NIST, are already playing an important role, vis-a-vis critical technologies. I think within the DOE laboratory system, there is a fairly long history of taking R&D to a product, in some parts of the laboratory complex. I think that that history and that culture does help to narrow the inevitable culture gap that exists between Federal laboratories and private industry when you are talking about taking R&D to a product. I think that the DOE laboratories have a long history of inherently multi-disciplinary interactions within their walls.

I also think that to address a point that Congressman Ritter made earlier in the hearing about the need for long- term orientation and commitment—I think that having Federal laboratories as a continuing entity—and this is true of the DOE laboratories—I think is very important. The question is sometimes put to us as, why don't you just contract everything out to a consulting firm of one kind or another? They can always go out and hire people to do the job. That's precisely the issue, I think, that DOE laboratories provide sort of a reservoir of world class scientists and engineers, who are there and have a long-term orientation towards important and critical technology subjects.

I think the labs have a track record, vis-a-vis getting technology out to the market place. Since 1985, some 140 spin-off firms have been formed as a result of research and development undertaken at the DOE laboratories. Since the beginning of the 1980s, I think there have been something on the order of upwards of 360 licenses for technology developed at laboratories that have been negotiated.

Of course, the laboratories have been substantively involved in many of the issues, as I alluded to earlier, in materials, both on the synthesis and processing side, as well locations for user facilities for characterizations for new and advanced materials. Certainly, in the energy technologies area, they have a long and distinguished history. In the area of supercomputing, when Seymour Cray invented or built his first supercomputer, he sold it to Los Alamos.

I think that the labs have a long history in interest in scientific expertise in the area of radiation biology that over the years has given them the foundation for getting into DNA research, and I think that has led to their participation in the human genome project.

To pick up on a point that Dr. Phillips made earlier about getting industry together, I think that the labs have the continuing role in playing a neutral meeting ground for industry, making it easier for companies to work together. He brought up the example of Los Alamos working together with Hewlett Packard and Dupont.

So I think the labs have a track record. I think that the Department's own thinking and planning along these lines are being strengthened by things such as the National Energy Strategy, which has a whole section within it, all on the role of technology transfer, related to energy. I think that the labs will continue to play an important role, certainly in DOE's vision of its technology posture towards industry in the future.

Mr. VALENTINE. There are some members of the subcommittee who have been here today and have not been with us the whole time, who might want to submit questions within reason. We would appreciate it if you would consider that.

We thank you very much for being here today, for your testimony, and for the other contributions that you make.

With that, the subcommittee stands adjourned.

[Whereupon, at 4:30 p.m., the subcommittee was adjourned, to reconvene at the call of the Chair.]

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